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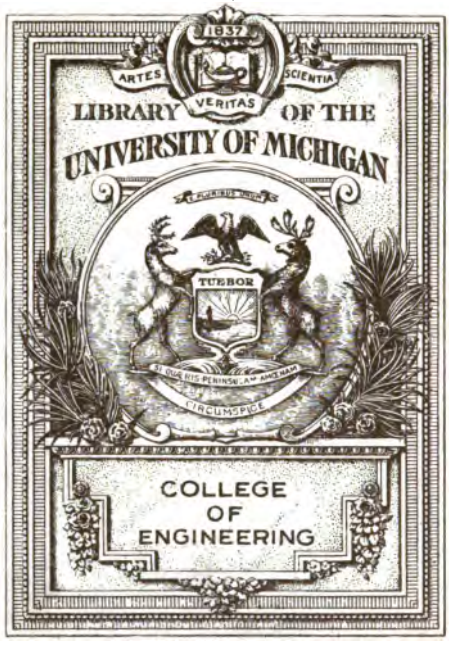
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INAUGURAL ADDRESS

BY THE PRESIDENT,

Mr. JOSEPH NASMITH,

DELIVERED SATURDAY, 9th JANUARY, 1897.

The past year has been notable in many respects, but in particular it has seen what is probably the high-water mark of that foolish panic which from time to time seizes the public mind with reference to our industrial prospects. The culminating point was reached when Lord Rosebery and Mr. Stead gave their imprimatur to the book which was published under the title of "Made in Germany." Both these gentlemen appear to have accepted all the deductions made with singularly childlike innocence, and neither thought the matter sufficiently important to inquire critically into the statements contained in the book. More recently, Dr. John Hopkinson has predicted that the industrial supremacy of this country will pass away with the utilisation of the water powers of the world in producing electrical energy capable of supplying power over a large area. It has been well said "Threatened men live long," and although this adage may be trite, it possesses sufficient truth to be of some comfort. It is true that near the close of the year we have had some utterances which serve as an antidote to the lamentations of our modern Jeremiahs, and it may be well at the present juncture to survey the field with a view of seeing what lessons are available. Let us "nothing extenuate and naught set down in malice." The day has gone by for the monopoly of manufactures of all classes to remain with any single country, and, although delayed by the restrictions to free

intercourse which are found in the various tariff laws existing, there will come a time when each country will produce that class of goods for which, by reason of its natural resources and the skill and industry of its population, it is best fitted. There is convincing evidence that we have no cause for serious alarm, although there is plenty of room for increased vigilance.

The subject is complicated by the difficulty of obtaining sufficient data founded upon a basis which permits of a correct comparison being made. For instance, the prices which rule at one period for any particular article are much higher than at another, and as, in some cases, it is only possible to make comparisons between gross values it is obvious that the figures given must be subject to the correction due to their variation. Thus the well-known index figures of Mr. Sauerbeck, which are based upon the average prices of a certain number of commodities in the period 1873-77, which is the unit of comparison, show how misleading a mere appeal to values may be. Calling the unit 100, the index number in 1891 was 72, in 1895 it had fallen to 62, and the average of 1896 is about 61. It is obvious that a comparison between the values of goods in any two periods must be vitiated unless due allowance be made for the decrease in price. Further, the condition of various markets at different times must be taken into consideration. Such an occurrence as the existing famine in India, the financial disturbance caused by the Baring failure, a great change in the incidence or amount of a foreign tariff, may so seriously affect a market as to entirely prevent a fair comparison being made. It is only possible to gauge the progress or otherwise of an industry by taking a survey over a period of ample length, and by bringing into our purview a large number of factors which a journalist of the type of the author of "Made in Germany" is quite incapable of taking into

account. It is not, however, the purpose of this address to deal with, otherwise than incidentally, the growth or decline of the volume of our foreign trade, but rather to see what lessons may be learned, so that "out of this nettle danger we may pluck this flower safety".

Among the factors which affect the problem there are three which have supreme influence. These are :—

First—The economic effect of improved appliances.

Second—The adoption of the best commercial methods ; and

Third—The fullest development of the skill of all those engaged in an industry, and especially of the leaders.

It is hardly necessary in addressing an audience such as this, to dilate upon the effect of improved appliances upon the power of competition. There are few members of this Association who do not daily come into actual contact with the problem how to produce some article at a cheaper rate. Although this tendency is most marked in those departments of industry where the constant repetition of the same operation is possible, it is none the less noticeable in other branches. Indeed, the very perfection which has been reached in this respect is the cause of other difficulties which in their turn add to the task. In all engineering industries, and more especially in those in which machines of one class containing a number of similar parts are made in large quantities, the most complete system of employing special appliances is found. But it is equally true that in other industries, apparently much more simple in their nature, such as, for instance, the manufacture of iron and steel, the same process has been going on. Thus, in the production of steel rails, this generation has seen an enormous advance. It is only by looking back a few years that the magnitude of the step which has been taken is seen. Ingots were cast, allowed to cool, and were subsequently re-heated and hammered into

billets of suitable size for rolling. The billets were again re-heated and rolled into rails. Compare this process with the beautifully ingenious method of to-day. The ingot is cast, solidified in the soaking pit, formed into a billet by the cogging mill, and at once rolled into a rail. After the ingot has been taken from the soaking pit, the amount of handling it receives is practically reduced to a minimum, for the elaborate system of live rollers and elevating tables enables all but the most necessary manipulation to be dispensed with. All this is of course a mere commonplace, but its effect upon prices is enormous, steel rails being sold at a rate which makes one wonder where the profit comes in.

Even pig iron has followed the same law. The operation of smelting iron is one which at first sight calls for very little skill on the part of those tending a blast furnace. It only requires the roughest of labour, and yet in this, as in all other industries, the cost of producing pig iron has steadily fallen. Improved appliances here, as elsewhere, have diminished the price by leading to an increased output without increasing the charge for labour, the only charge which does not decrease being that for royalties. The same feature can be discovered in every direction, and this factor alone is sufficient to explain the cheapening of prices, if it is not wholly responsible for that movement.

Perhaps there has been no single appliance which has had a wider influence upon the methods of producing parts of machinery than that type of machine which is included in the single name of milling. It is nearly impossible for us to conceive of certain classes of work being done with the accuracy, and at the price which is now common, without the employment of this type of machine. All kinds of flat surfaces are produced by its aid with celerity and exactitude, while it also lends itself admirably to the production of profile work. When considered

in connection with its adjunct the emery wheel, the introduction of the milling machine marks an epoch, and has completely changed the character of the procedure previously followed in making certain articles.

This portion of the subject need not be elaborated. It is so familiar that it is the merest platitude. It will suffice to remind you that one of the direct consequences of the adoption of the newer methods and appliances has been such a subdivision of some operations as to involve a fresh organisation of labour. Instances will be well known in which the making of a single article, as for instance the matrix used in the linotype machine, or the spindles which are made for ring spinning machines, involves the handling of the article by fifteen or twenty work-people, each of whom is charged with the performance of one operation, forming possibly a small portion of those which are needed to complete the whole article. This necessitates the design and employment of a large number of machines or appliances, each of which is intended to aid in effecting one of these minor operations, and calling for the attention of a workman specially trained in its use. In this way there has been silently worked a revolution which is not always fully appreciated even yet, and which has had no less an effect than the elevation of the machine tender from a subordinate to an important position in the economy of a workshop.

It is in consequence of the facility of subdivision, which the ingenuity displayed in the production of special appliances has brought about, that in all organised industries the labour cost of an article continually tends to decrease. Probably because the economic change which has taken place has only been partially appreciated we find people still making a great fuss about wages. As a matter of fact, the rate of wages is not necessarily a guide to the labour cost of an article, and a wider recognition of this fact would prevent a good deal of trouble.

It may be urged as the paramount consideration that it is the labour cost and not the wages which ought to be taken into account, and although there is a certain connection between the two they are not so coupled as sometimes seems the case. Moreover, as time passes there will be less connection than in the past, for the efforts of engineers especially will be directed towards the provision of appliances which will enable high wages to be earned while the labour cost of the article is continually reduced. It is not necessary to render this address tedious by an elaborate statistical proof of this proposition, and it will be sufficient to give one or two instances.

Public attention was directed with some force a short time ago to the wretched condition of the "nailers" in the Dudley district. Labouring with great intensity under conditions which recall those of mediæval times, they were unable to earn more than a small pittance, equal at the most to 15s. per week. In America labour conditions of this kind are impossible, owing to the economic circumstances existing, yet nails are made at a labour cost far lower than that common in the Dudley district. The output of a worker in an American nail mill amounts to over 2½ tons per week, while the Staffordshire nailer, working on his old method, only produces 2 cwts. Of what avail is it that the workman in the latter case earns 15s. only and in the former £6 per week? The labour cost per lb. is in the one case ·8d. and in the other ·257d. Thus the earnings are eight-fold greater in the case of the American workman, while the labour cost is only one-third that of the nail produced by the English workman. This is possibly one of the most striking cases which it is possible to cite, but it is only illustrative of a principle which runs through all industries. It is when this fact is most thoroughly recognised and appreciated that we see the greatest efforts put forward to economise labour cost. The latter has fallen in some cases to such a level that it seems

practically impossible to further reduce it, and a large increase in the earnings of the workpeople represents often a small fraction added to it. Thus the whole labour cost of producing a Waterbury watch of the ordinary type is less than 50 cents, say 2s., a fact which enables one to understand and appreciate the extremely low price at which it is sold. It is obvious that, if by improved appliances the speed at which any one of the operations can be effected is increased, the workman could with ease earn equal wages while producing a larger number of the same article. Thus by the aid of two machines, specially devised, two men and two boys produce from 1,200 to 1,500 springs per day when previously the output was only 1,000, twelve men being employed. Is it not obvious that in the first case it is possible for the workman to earn a far greater aggregate sum, while the cost per spring is largely reduced? If it were necessary these instances could be multiplied, but they will serve to illustrate the principle which is being laid down, viz., that it is the labour cost and not wages which is the determining factor, and that there is not necessarily a direct connection between them. Indeed it may be asserted that they are often in inverse proportion, and that the more highly organised an industry is the greater is the tendency for that to be so.

It is, of course, the fact that nothing has so much influence upon this problem as the possibility of making articles in large numbers, and it is in this direction that much remains to be done by engineers. Nothing presents so hopeful a field for the future efforts of constructive engineers as the design and manufacture of machines which will enable manufacturers to produce all kinds of articles in the greatest possible numbers in any given time. Wages become a secondary consideration under these circumstances, and although a change in the rate paid may for a time affect the economic conditions, it is

not long before the skill of the constructor has placed him abreast of the new conditions. The repetition of work which more and more is becoming the rule, whatever may be its demerits artistically, is beyond doubt the great factor in the cheapening of production. Thus although in this country we hold a high reputation for printed cotton goods, and continue to increase our trade in the same, we do not produce cotton prints so cheaply as they do in the United States. The fact is easily explained. In the last-named country, with its gigantic home market, it is possible for calico printers to run for months on the same pattern, whereas an English printer can only run for a few days at most before he must of necessity put in a fresh pattern. The great number of patterns demanded from an English printer involves the provision of a large number of engraved rollers the aggregate cost of which is very high, in addition to which he has to reckon the loss of time involved when changing the machine to print another pattern. The same thing applies in other departments, and in none more than engineering. The steam engine maker, who is able to persuade his clients to take an engine from patterns which have been used before, is enabled to quote a lower price than would be possible if he was compelled to make entirely new designs. In the smaller sizes of engines this system of specialisation has more or less been initiated, but in the larger sizes it has not yet been found practicable to any large extent. No doubt others beside myself are conversant with one case at least in which several sets of engines of large powers have been made from the same drawings, with the inevitable result. Precisely the same benefit has accrued from the classification of locomotives by the large railway companies, and there is plenty of room for further movement in this direction.

Specialisation is indeed in the air, and, although in many departments of engineering it has been thoroughly carried out,

there are others in which this aspect of the subject is worthy of more attention. Of these, the making of machine tools is perhaps the most prominent. One of the surprises of the present day is that in the very home of the modern machine tool, designed and developed by Roberts, Nasmyth, and Whitworth, we should find so many machines of Transatlantic origin. Further, a German firm, working on American methods, is also gradually extending its market in this country. At the late show of cycles in the Crystal Palace one of the features was a superb exhibit of American-made machine tools, and it is stated by persons who are in a position to know that they are being widely purchased by cycle makers. This is not as it should be, and it is desirable, if possible, to find out the cause of this preference. Time will not permit of a critical examination of the subject, nor of many others to which reference will be made, but at least one lesson may be learned. American tool makers stick very closely to a definite plan of procedure. They limit the range of the machines which they make, and within these limits they fix the design and construction of each machine. They practically say to their customers, "We have made it our business to understand thoroughly the work which our machines will be called upon to do; we have thought out the problem how the machine can be best made to suit the work, and we have designed and constructed a machine which, in our judgment, is the one most suitable for the purpose. There it is; if you like it we will sell it to you for a given price, if not, we must ask you to look elsewhere." It is a strange thing, but true, that the same customers, who will worry an English maker's life out by demanding all kinds of small changes in the machine he is making for them, will accept with admirable docility the conditions of his American rival. Why should this not be so? In the one case there is the specialist, with an imperious belief in his own knowledge, and in the other a

maker, knowing he knows, but, owing to custom and tradition, unable to assert himself. There are two lessons to be learned from the American invasion, the one the necessity for makers to think out the details of their machines and then stand by them, and the other the necessity which exists for the greater specialisation of manufacture. An examination of the catalogues of a firm like Messrs. Brown & Sharpe shows how small in comparison is the range of their manufacture as compared with that covered by any firm of equal importance in this country. How many machine tool makers are there who will not make with equal willingness a lathe of 7-inch centres, a universal milling machine, a planing machine to take in seven feet square, or a punching and shearing machine for ship plates? Surely it must be admitted that the latter procedure is far less conducive to profitable excellence than that followed by their rivals. It must not be forgotten that price after all determines the direction of trade, there being no exception from this rule under present economic conditions. In all departments of engineering this is being felt, and there is no reason to expect that any will escape. It may well, therefore, become matter for serious thought whether the tendency observable in all other departments of engineering could not be extended to this with equal success. There is no intention to dogmatise on the matter, but rather to state the case suggestively with a view to lead to a thoughtful consideration of the subject.

The question of improved commercial methods is one which is rapidly becoming distasteful by reason of the "damnable iteration" of it. The burden of Mr. Williams's book is that Germany, by improved commercial methods, is overtaking, nay, even passing, us in the race. Consular report after Consular report says the same thing, until it almost seems as though this was becoming the one item available in the way of recommendation. Indeed when one reads a large number of

these reports it wants a well-balanced mind to resist the conclusion that as a nation "we have done all the things we ought not to have done, and left undone all the things we ought to have done." It becomes, however, somewhat ludicrous when our Consul in the Canary Islands expends several pages in elaborating these charges, and holding up our German rivals as an example. Our total trade with the Canary Islands during 1893 was £663,000 out of a grand total of £1,200,000, and it is this instance which has elicited what is perhaps the longest, if not the gravest, indictment of our commercial policy to be found in these interesting documents. One of the principal charges made against us is that we do not suit the convenience of our customers. This means, first, that we do not give outrageously long credits, that we will not make up certain classes of goods gaudily and showily, so as to take the eye, and look as well as better makes, and that we will not invoice them in foreign weights and measures. With reference to the first of these charges, German makers, to whom we are bidden to look for example, have not found long credits an unmixed good; and one may have, without lack of charity, a suspicion that they have bought some of their trade too dearly. It is neither necessary nor desirable to go at length into this matter, and it will suffice to point out that the British merchant and trader is as well equipped and enterprising as any other. The history of the past has not justified many of these criticisms, for assuredly no country ever built up such a vast fabric as we have done without enterprise and without taking some risk.

With regard to the second point, it may be asserted even at the risk of being charged with insular conceit that a proportion at least—and not a small one—of the trade which is being obtained by our rivals is got by means which can only be characterised in one way. In saying this, it is not forgotten that there are many articles of foreign manufacture which find a

market by reason of their excellence, but it is idle to shut one's eyes to the flood of rubbish poured on to the markets of all countries, fraudulently marked and manufactured. Quite recently an exhibition of various classes of goods sent into our colonies was held in London, and a personal inspection was sufficient to show that their sale depended mainly upon their cheapness and not their quality. It is practically impossible to understand how even "the heathen in his blindness" will continue to buy some of them after a short trial. Figures are slowly proving that our trade is not permanently suffering, except in certain articles which are better than ours, mainly because greater attention has been paid to them by foreign manufacturers. Remembering, however, the chief purpose of this address, which is to indicate remedies rather than reiterate complaints, nothing more need be said on this point.

Perhaps the complaint which is made as to the inconvenience caused to our customers, and the consequent loss of trade to ourselves, by our system of weights and measures, has more in it. Even here one cannot help thinking that there is too much of the parrot cry. It is asserted in round terms that English traders send out catalogues in which all the descriptions and prices are in our own tongue, that they will not quote in the currency and weights of the country to which they purpose sending the goods, and that even if they do, delivery is only made at English ports. It is, of course, difficult to say to what extent this general allegation is true, but it may be asserted with confidence that, so far as this district is concerned, it is not so generally. To quote "franco" is as common as to write a letter with Lancashire engineers, and the advantages of the slide rule were first made apparent to me by seeing how rapidly a quotation for a quantity of machinery, delivered in Central Europe, was arrived at by its use. In this case the quotation was made in marks, and included cost, freight,

insurance, packing, and delivery at the railway station nearest to the mill. There must be many members who can testify to similar cases. At the same time, it may be pointed out that to send anything but the baldest announcement in English is absurd, and that it is no good going to the expense of collating and getting up a catalogue to send to people to whom, outside the pictures, it is of no value. Further, the translation of English weights, measures, and currencies into those of Europe is not a difficult matter. Exchange fluctuations may be met by making the prices high enough, and regulating discounts. Although it may be that this is not perhaps the most important matter, yet it is one upon which to some extent depends the successful conduct of business, and is worth careful thought. It must not be forgotten that it is upon such small things that success or failure often hinges, and this renders the matter of importance.

With regard to the wider question of the adoption of the metrical system of weights and measures, it is not possible to deal with it, even approximately, in any such time as can now be given. While it may be admitted that a system in which each term is a multiple of some unit has advantages when viewed as a method of calculation, there are a number of considerations of great moment which require taking into account before so radical a change is made. Men so widely diverse as Sir Frederick Bramwell and Mr. Coleman Sellers have expressed themselves as averse to a change, and given cogent reasons for their opinions. In the meantime, it may be pointed out, that for very fine measurements the employment of micrometer gauges, which permit of readings so fine as thousandths of an inch, is becoming very common. So far as practical delicacy of measurements are concerned, there is no reason to be dissatisfied with the present system, and in many departments they are the rule in present day practice. At any rate, the practicability or

otherwise of the adoption of the metrical or decimal system of computation in this country does not affect our competitive power abroad. It is, as said, easy to translate the figures of one system into terms of the other, and no difficulty is experienced in working to metrical measurements. Still less trouble is found in invoicing goods in kilogrammes, kilometres, or francs, and there is, therefore, no excuse if we allow this to be a hindrance to foreign trade.

Another matter to which attention is required is the matter of transit charges. The railway companies are not altogether to blame for these. Their capital expenditure has been largely increased owing to the grasping policy pursued by landowners and others whenever extension has been required. When due allowance has been made for this, however, there is no doubt that transit charges are too heavy. The railways of this country carried in 1895, according to Mr. Wolfe Barry, 834,000,000 tons, and it is easy to see that a small reduction in the rate per ton becomes a matter of importance. It is not necessary to recapitulate the figures, which have been so often and recently stated, with reference to the saving effected by the Ship Canal; nor the startling figures showing the growth of the port of Hamburg. Cheapness in each case is bringing traffic, which in its turn leads to further work being done in the ports. We are beginning to be conversant with the meaning of Conferences, and their action is illustrated by the fact that American piece goods are carried to the East *via* Liverpool at 27s. 6d. per ton measurement, while for English goods of the same nature the charge is 55s. per ton, which is equal to about 4d. per piece. Bar iron is another article which is carried from Antwerp or Rotterdam to the East Indies for 10s. per ton less than from Liverpool. Is there any reason for wonder at the rapid growth of the Continental ports or of foreign-owned shipping? It has

often been cause for remark that German wire drawn in Westphalia is more cheaply put on to the London market than that made in Birmingham, and it is evident that when this is the case the cheaper sea rates charged from Hamburg will increase the gift to the German makers. Thus the rate per ton for nails from Birmingham to East Africa, including 113 miles of railway journey, which is charged 18s. 4d., is £3. 17s., while the same quantity carried 300 miles by rail to Hamburg and thence carried by sea is only £3. 6s. The difference is a profit and a not inconsiderable one. It is little use piping to deaf ears, but if the Conference shipowners are content with 17s. 6d. per ton for American drills Liverpool to the East, while they exact 55s. from their own countrymen, they are sorry patriots, and are doing their best to kill the goose which lays the golden eggs. Our Liverpool friends have been alarmed, and not too soon, at the growth of the trade of Hamburg. Liverpool and London are the chosen homes of the Conferences, and it is to be hoped that they will have to bear the pinch of competition still more in order to drive the lesson home to their dull comprehensions. I do not hesitate to say that many of the losses we, as a nation, are bewailing in connection with our trade are owing to the grasping policy of the shipowners. We in Manchester would not be unwilling to recognise the justice of the demand of Liverpool on the railway companies for lower rates if they would co-operate in obtaining a reduction in over-sea rates. "Physician heal thyself" may well be said to them, and when they set themselves seriously to the consideration of this question they may look for the cordial sympathy and co-operation of traders throughout the country. It is surely time that some strong effort was made to deal with this matter, but it will right itself if left to time. The trade between Manchester and the Eastern European ports has grown to dimensions which show how greatly cheap freights are appreciated, and

this is but a sign of the times. It is more than probable that the loss of trade experienced by the ships of this country owing to high freights will lead to a serious consideration of the whole subject. No single interest can expect to prosper at the expense of every other, and our shipowning friends will one day have this painfully impressed upon them. It is of no use for manufacturers to be continually alive to the necessity for small savings, and always on the look out for means whereby they can produce economically, if, after all, their efforts are to be nullified by the imposition of transit rates which are in excess of those charged to their competitors. This is one of the most important factors in the situation, and requires very serious and careful thought. It plays no inconsiderable part in the economy of a country like this, where manufacturing is largely devoted to the supply of distant markets, in which a determined and energetic competition is always maintained. So far as engineers are concerned, they have done their best to aid the shipowner by the construction of appliances by means of which the cost of ships is constantly reduced and their economical working ensured, and they, in common with other traders, have the right to demand that shipowners shall bear their share of the burden, and not handicap the constant efforts of others to maintain the trading interests of the country.

Whatever may be our opinion on the questions which have been hitherto touched on, there will be little difference as to the desirability of developing to the largest possible extent the skill of those who are to carry on the industrial work of the nation. The factors which have been detailed in the early part of this address are themselves hindrances to the training of artisans in the sense in which that word is commonly used. The subdivision and organisation of work brings in its train the necessity for the employment of operatives whose daily work is the performance of one specific act. Thus in making ring

spindles one man does nothing else than centre, by the aid of a small drill, the upper end of the sleeve in which the steel spindle fits. He is merely preparing the sleeve for drilling, which is done by another man. This is an operation demanding vigilance and assiduity, but it is one which is readily learned. The same may be said of the numerous operations which are needed before the completed article is obtained, so that we have in this instance an example of that tendency which makes expert operatives, but not handicraftsmen. The same kind of thing is going on all round, and the common experience of large numbers of our members will enable them to recall similar cases. It is, of course, not in every department that so limited a range of work exists, but even in the construction of large machinery the tendency can be observed within the limitations imposed by the class of work carried on. It is obvious that any such method cannot produce handicraftsmen, nor, on the other hand, does it call for them. The unfortunate part of the matter is, however, that the system tends to lower the general standard of skill, and thus, unless some other means are found, gradually causes a deterioration in the men available when the occasion calls for them.

It is a common experience now to hear people engaged in any industry declare that they cannot get workmen of the type formerly available. Very little thought is needed to show that it is idle to expect such a thing, and, moreover, the field of selection will diminish in area as the specialisation of work proceeds. How, then, are we to fill the gap? How are we still to produce that class of man, with that practical skill in an art, which has hitherto been the strength of this country industrially? The reply can only be—by the adoption of some system of training by which the technology of the art is communicated. This is thorny ground, and is one upon which, even in an Association like this, there is much difference of

opinion. There is no doubt that, to-day as always, the motto of Horace, "Experientia docet," is true, the limitation lying in the difficulty of acquiring the experience. The training ground has changed, and just as it would be foolish to teach the soldiers of a country like Holland the system of warfare suitable for a mountainous district, so in like manner it is inadvisable to look to the old methods of training when the conditions have become so widely diverse. It is clear that while nothing makes a workman expert like the actual carrying out of an operation, if it is desired to fit him for the performance of some work outside his present occupation, his training will have to be given elsewhere than in the place of his employment.

In the cotton spinning industry, for instance, although it is an apparently simple operation, there are men who spend all their time in the performance of operations forming one portion only of the whole system. The necessary organisation of the mill shuts them out from the opportunity of acquiring any practical knowledge of the work in other departments. There are many of them who are content with this state of things, but there are some who are desirous of getting for themselves a knowledge of the whole treatment from beginning to end. It cannot be doubted that, if they do so, they will be none the worse, and may easily be better operatives in their own branch of work. How can they get this information? It must be remembered that we do not need to provide for those who settle down and are content, but it is of national importance that we do so for these bright and intelligent youths who aim at the acquisition of fuller knowledge. In Oldham a few earnest souls solved the problem by organising, with immense labour, a school, fitted up with the best appliances they could get together, in which the carding-room and mule-room hand could intercommunicate their knowledge to their mutual advantage. They knew that within the mill they could not

so meet in friendly, helpful intercourse; they realised that upon the possession of full knowledge much depended, so far as their future was concerned, and with a rare courage and foresight they banded together, to afford facilities for all those who were willing to make the sacrifice to give and receive the necessary essential supplementary knowledge. It is upon similar lines that we must proceed if we are to maintain our high position.

The words "technical education" are received even yet among many engineers, if not with open derision, at least with some veiled distrust. It is one's lot to discover the latter from time to time by an expressed dislike to take students into works after they have been technically trained. This arises for the most part from a misconception of what technical education is and what it aims at. It is quite true that in some respects it has been wrongly stated, and has been interpreted as a mere training in the theory of a subject. Against this the practical instincts of our countrymen have not unjustly rebelled, but it is by no means the true concept. If any one thinks that within the curriculum of a technical school is to be found all that is needed to make a youth a competent practitioner of any art or industry he had better dismiss such a notion at once. On the other hand, if it is thought that in the future this country will continue to hold as prominent a position industrially as it has in the past, without a much more thorough training in the theory underlying its industries being given to its rising youth, that also must be dismissed. The fact is that it is as desirable to steer clear of the Scylla of pure theory as it is of the Charybdis of the old rough and ready practice. Only between the two is found the safe course. We cannot in this age of competition afford to pay for mistakes. These may be made as readily by too slight an acquaintance with theory as practice, and it behoves us to see to it that we steer our course so as to avoid both dangers.

No one who has studied the subject with a sincere desire to know the truth can fail to see that in certain departments of industry the most thorough theoretical training is of vital importance. Thus in the chemical trades, Germany, by reason of her better equipment in this direction, aided by our defective Patent law, has quite outstripped us. All that beautiful range of colours which are now made from that foul product, coal tar, we owe to the research of German chemists, although the discovery was one of English origin. To-day, in spite of their pre-eminence in this department, German chemists continue to labour as though they still had the field to win. Take another instance. It is impossible yet to forecast with anything like precision the future of the applications of electricity. Sir Wm. Forwood, for instance, recently said that the economical value of electricity, as shown by its use on the Liverpool Overhead Railway had been a revelation to him. It is true that we have already seen an enormous extension in the electrical industry, but it is self evident that we are only touching the fringe of the subject. In this art the close and accurate observation of natural phenomena is of the highest importance, and we have already placed on the roll of fame the names of a few men who have done much in this country to encourage this disposition by their investigations. Crooke's radiometer was the precursor of the Röntgen rays, and Faraday's quiet investigations lie at the root of most of the work of the present. But in the future, electrical engineering, and electro chemistry demanding also the aid of engineers, are bound to call for men able by their training to practise them, and it is not the research and knowledge of the few but of the many which will be needed. The Germans are wide awake to the fact, and are equipping in various places schools of great magnitude where the technology of the subject can be taught. Stuttgardt, a town of only about 50,000 inhabitants, has spent over £200,000 in the erection and equipment of a

school for the study of electrical engineering in all its departments, this being the finest school in the world, the equipment having cost three times as much as the building. It is, of course, not to be expected that even the students of such a school as this will go out and immediately carry out large works without mistakes or difficulty, but the habit of clear thinking which their training will give them will fit them admirably for meeting and overcoming the difficulties. Upon the men able to carry into practice the science underlying a subject will fall in the future, as in the past, the heat and burden of the day, but they will have to be as receptive of the science as of the practice if they are to conquer under the new conditions.

The evolution of the steam engine forms another example of the true correlation of theory and practice. It may safely be asserted that it was not until the steam engine began to be studied scientifically that its real improvement began. Any man trained in a haphazard way can, and did, make a steam engine; but it was the peculiar function of those who began to work out the application of the theory of thermo-dynamics to place its construction on a true basis. The importance of avoiding initial condensation, the reduction of clearance spaces, the necessity for complete drainage, these and many other points have come to engineers from the labours of a long list of investigators into the pure science of the subject. Without the long, patient, and, to some minds useless, investigations of Joule, the whole theory upon which at present the steam engine is constructed would have been non-existent. How much was elucidated when he first clearly proved the absolute relation existing between heat and work, and how wide reaching has been its effects. We cannot all be investigators, but do not let us on that account undervalue the work. In the future, with the enormous increase in our knowledge of nature, the investigator

will play an important part, even in so essentially a practical art as engineering. Although this work must be done by a few, it will require well-trained minds to take advantage of it. In this, as in other spheres, it will be peculiarly true that "other men have laboured and we have entered into their labours."

In pressing this aspect of the question upon you, it is not intended, as was said at an early stage, to urge that all that is needed for an engineer lies within the ambit of what is commonly called technical education. This must always be supplemental to, or perhaps better, complemental of practical work in the workshop. It is, however, because the latter, in its wider sense, is becoming more difficult that the need for further training becomes more apparent. Members of this Association will not take kindly to conditions under which only those who can pay a large premium can acquire a sufficiently all round knowledge to enable them to take the leading positions. We must, if we are to maintain our national position, take advantage of the best brains wherever they are found, and the members of an Association such as this should see to it that as far as in them lies opportunities for thorough training shall be available for all those who have the intellect and courage to take them. For the purely scientific investigator we have in the past been, and are still more at the present, providing ample means of research. Let us see to it that those whose lot and inclination leads them into the practice of an art have the opportunity to acquire it in spite of the increasing subdivision and specialisation prevailing in our workshops. That indeed furnishes the basis for the demand, and renders it imperative that it should be met.

The matter is even more important if it be reviewed from the point of view of ensuring a full supply of competent men to become the rulers in our workshops. It is absolutely necessary that they at least shall have a training which

enables them to look at the subject from all sides, so that they can the more intelligently perform their duties. Many firms have a reluctance to take into their works youths who have continued their education long enough to acquire a thorough scientific training, resulting perhaps in the obtaining of the degree of B.Sc. Let me say, that in order to get admission into some of the Continental schools—Zurich, for instance – the knowledge required is nearly equal to that needed to reach the stage named. It is urged that the old plan of workshop experience by day and the necessary studies in the evening is the best. Apart from the question as to how far it is fair to subject the physical endurance of a growing youth to such a test, and the further difficulty of overtime, there is the more important question whether it is not advisable to give him such a preliminary training as will enable him to grasp and profit by the revelations of a workshop experience, and fit him to go on with his higher studies in his limited leisure. To send a lad to work in an engineering establishment at 14, when he has not mastered enough of any basic science to enable him to go into the higher branches of it with ease, is to condemn him to a task which he may accomplish, but only at a great loss of time and energy. To keep him at school until he is 16, and in the meantime give him a systematic and graded education so that he will acquire so much of mathematics and mechanics as will enable him to understand the drift of the various operations going on around him, is by far the wiser course. Then the translation of abstract theory into concrete facts, which he sees in operation every day, becomes a work of intense interest to him, and has an added significance.

What I personally feel about the matter is that it is most difficult to dogmatise. There are some industries in which a complete mastery of the theory underlying them and of

experimental or research work are of absolute importance, while there are others in which an early acquisition of practical experience is equally important. The training which is the best in one case is far from being so in the other. In all engineering industries workshop practice must take the highest place, and without it the productive engineer is impossible. There are, it appears to me, two things to remember in connection with this subject. The one is that the purpose of all education is not to cram with information, but to induce the habit of systematic thought. Technical education should be, therefore, the training in systematic thought on a specific subject or subjects. If it fails in this it fails in all. The second point is that the purpose of all technical training is to fit a man to be a producer of the best type. That is to say, he must be able to so plan or carry out work that it is produced in the best manner possible, at the lowest possible cost. To do this requires not only systematic thought, but experience in the handling of materials and men, the last probably the most difficult. This is only attainable by that actual contact with the work, which can be got in a workshop. Our aim should be to bring into legitimate alliance these two partners. The excessive predominance of either will prevent the full accomplishment of all that is possible, and the extent to which either should predominate can only be settled by a full consideration of the whole of the circumstances of each case.

Signs are not wanting that there is a revulsion, more or less marked, on the Continent, even in Germany, in the feeling with regard to the method of training which is there adopted. The experience there is that the students of the Polytechnicum arrive at an age when the drudgery which is inseparable to the early stages of practical training becomes nauseous to them, and in very few instances is it undertaken. The difficulty which exists is a real one, for it is found that the adult students seek

to find an office in which the practical part of the training can be shirked. The Whitworth scholars of this country are in a better case. In many instances they have been engaged in the shops during their preparation for the examinations, and have thus acquired that preliminary general knowledge which fits them for again taking up the work at a later period. Yet even in their case it is found that many of them drift into official or other similar positions and are lost to the industry in a productive sense. It is worth repeating that what we want to meet our foreign rivals are men who can put their brains into productive work, and there will always be some trouble in that respect with men who remain at college until they are 23 or 24. It must be borne in mind that employers cannot make posts indefinitely, and that in their own interests they are likely to confer them on the men who have been trained under their own eye. After a long and expensive education the graduate of undoubted scientific knowledge finds himself confronted with offers of subordinate positions at low salaries, and in many cases he is too apt to think them beneath his capacity. The result is that some teaching appointment or the like opens up, he takes it, and becomes lost to the profession as a producer. I have had during the past twelve months the opportunity of hearing several stories of this kind, and have met, on the other hand, with one case where a young fellow, after taking his degree, went into a shop and started at a low rate of wages in order to get practice. He is rapidly improving his position, and in a very short time will, by reason of his training, be specially fitted for a post of the highest order. It must not be forgotten that the trained intellect acquires all knowledge rapidly, and when the student has the courage to take the course indicated the result is favourable. I believe, however, that the best system is to educate youths systematically until they are 16, pass them into the shops, and then

into a drawing office, and encourage them to enlarge their studies as they find opportunities. In this way we will make productive engineers of the best class, which is what we want to maintain our position.

Hand in hand with the proper training of our youth must go the most effective organisation of our workshops. As far as is possible the end should be seen from the beginning, and in this the production of thoughtful men will aid considerably. It is more and more evident that brains will tell in the struggle which is going on. Organisation is one of the most important functions of the trained mind, and as "order is Heaven's first law," we cannot go far wrong in taking it as the cardinal virtue. It is, of course, quite true that there are classes of work which make organisation in the way indicated a difficult task, but there is much to be done even in these. Specialised industry must of necessity be organised, because the full advantage flowing from it is not realised until every man fits into his right place and does precisely the right thing. There will always exist special needs which are not in themselves important enough to employ a large workshop in which every department can be worked as a unit. The number of these, however, will year by year diminish, and there will be a great call for men who can bring everything into line as part of a great system. Unless this is effected neither the full value of either the human or material agencies available will be obtained, and thus the creation of an organised system of production becomes at once the cause and result of a better system of training than at present obtains. I have personally no fear of the result of our labours in the long run. The British mind may be slow but in the main it is sound, and, though we may be a little more leisurely than some in adopting the newer methods when they are put into practice, they are generally founded not only on new but safe lines.

Foreign competition is not a myth, and as the years pass on it will become less so. There are engineers in Lancashire who can tell you of the great success of firms like Sulzer Bros. in making stationary engines. In electrical work there are Swiss firms who are in the forefront, and in numerous other departments of engineering work we have competitors who are not to be despised. Count Fosco, in "The Woman in White," says "A wise man never undervalues his enemies," and this is the true spirit. On the other hand, we should not overvalue them. The continual iteration of our inability to compete is likely to do us serious injury in the minds of those to whom we offer our goods. The right course is to ascertain where a possibility exists of amending our efforts, and then putting into practice the lessons we learn. There exists in this country a class of writers whose *metier* is pessimistic wailing because the world is not run on their lines. No intelligent man bewails the presence of competition. Even in those countries which are blessed or cursed—according to the point of view of the observer—with a protective system, internal competition is often a very hard thing to bear. Thus the cotton mills in the Eastern States of America are said to have had the worst year for prices they have ever experienced, and the stocks of cloth are said to be larger than has been known. They are protected from external competition, but have not been able to escape that power within. All that we ask is that the competition shall be fair, and that forged trademarks and fraudulent imitations shall not form part of it. It is gratifying to note that the Cutlers' Society have been able to obtain a conviction against traders in the Egyptian courts, because of their forgery of trade marks and have obtained an order forbidding the use of the word "Sheffield."

I am afraid that I have wearied you with these discursive remarks, which I am painfully aware are not novel, nor do they

adequately discuss the various points touched on. Such as they are, however, they may afford some food for thought, and may present old friends in a new light. I am more than disgusted with the perpetual lamentations of our modern Jeremiahs, and would like to enter my protest against the painful exhibition of faint-hearted counsels which of late have been so freely offered to us. To my mind it is better to believe in our capacity than our incapacity, and although I should not care to see us imitating the rhodomontade of our American cousins, that is better than the despairing wails in which so many of our countrymen rejoice. The populace of these little islands are the most industrious, the strongest, and the most practical to be found in the world. Are we to believe that our right hands have lost their cunning, and because we are meeting a little opposition we are therefore beaten? The great empire which pays allegiance to the Lady who this year attains the longest reign of any of our rulers was not built up by that spirit. Insular conceit or not, I prefer to believe that we are able to cope with all our difficulties rather than to admit defeat on the first shock of battle. That we may see great changes in the character of our industries we may well believe and expect, but that in consequence we must surrender the position seems to be the most miserable *non possumus* ever propounded. Let us take heart of grace, learn the lessons of experience, and turn our faces resolutely to the conflict, assured that if we maintain intact the inherited spirit of the race we cannot fail.

It was moved by Mr. T. Ashbury, seconded by Mr. T. Daniels, and supported by Mr. Alfred Saxon, that the best thanks of the Members be given to the President for his interesting address.

The motion was carried with acclamation.

The President briefly acknowledged the resolution, and the proceedings terminated.

EFFICIENCY AND MANAGEMENT OF STEAM BOILERS.

READ SATURDAY, JANUARY 23RD, 1897,

BY

MR. ED. J. DUFF,

LIVERPOOL.

In these days of international competition for industrial supremacy, when the profits from manufacturing operations in many important industries leave a gradually diminishing margin between the items of profit and loss, it well behoves our engineers and managers of works to review their methods and conditions of conducting operations, with a view to economising in the use of raw materials, and to secure the highest practicable efficiency from the instruments with which they have to carry out their work.

The days when engineers could afford to ignore the latest steps in progress—and dispatch them as "new-fangled" notions—have now passed away, and rule of thumb and guess-work must be replaced by the results of exact measurement and calculation. Many of our "old-school" engineers are awakening to the new requirements, while the technical schools are preparing the foundations upon which our younger engineers will carry on their work. At present we find many works' engineers—possessed of considerable practical ability—who, in an intelligent but desultory sort of way, have picked up links of scientific knowledge in connection with a given subject, but who, for want of a few missing links, have not been able to grasp the full value of what they possessed, and were therefore

unable to apply the knowledge to any, or to very little, useful purpose. While I do not pretend to-night to add much to the sum of scientific or practical data in connection with my subject, I wish to link somewhat together the various facts bearing upon the economical use of fuel in steam boilers.

In striving to attain the practical possibilities of an operation, it is well to know what is the ultimate or theoretical limit beyond which we cannot go, and then endeavour to get as near that as possible. Therefore, to find out what is the theoretical limit of evaporation possible per pound of South Lancashire slack, we find the average composition from a number of samples from different pits to be :—*

Moisture.....3·05 %.

On dry sample :—

Volatile Matter		29·1 %
Fixed Carbon	58·04	= 70·9 %
Ash	12·86	
		100 %

The ultimate analysis giving :—

C	72·6 %
H	4·79
O	7·28
S	1·64
N	·71
Ash	12·86
	99·88 %

The heating value of this fuel per pound, if completely burned :—

0·726 Carbon at 8,000 units ..... =	5,808
0·389 Hydrogen at 29,350 units ... =	1,141
Total.....	6,949
Less evaporation of 3 % moisture ...	19
Total units ...	6,930

* By Dr. Ferdinand Harter.

Evaporating power per lb. of fuel if feed water is at 212° Fahrenheit = 12·9lbs. of water.

The heating value of the volatile matter alone is per pound of fuel :—

0·1,456 Carbon at 8,000 units	= 1,164
0·0,389 Hydrogen at 29,350 units...	= 1,141
Total.....	2,305

Evaporating power of volatile matter per lb. of fuel if feed water is at 212° Fahrenheit = 4·3lbs. water.

Hence the volatile matter represents 33·3 % of the whole value of the fuel, and unless care is taken that it is all burnt the loss from its distillation may reach 33 %.

The results of the above analysis and calculations show that for every one grain of carbon burnt the fuel evolves 9,545 units of heat.

One litre of CO_2 gas contains 0·585 grains of carbon, hence for every one litre of CO_2 passing into the chimney 0·585 × 9,545 = 5,106 units of heat have been generated on the grate.

If 100 litres of fuel gas are considered, then the amount of heat generated by them on the grate is the % of CO_2 × 5,106 units of heat.

100 litres of the fuel gas will carry away with them into the chimney different amounts of heat, depending first upon the temperature, and second on the specific heat.

On the assumption that a coal corresponding to the above analysis is burned without excess of air, the specific heat is such that 100 litres are equivalent to 34·8 grammes of water; but if the fuel gases are extremely diluted with air, then this figure will be much reduced.

To be on the higher side, take the highest of the two values, and say that the heat lost with every 100 litres of fuel gas is

3,480 units per degree centigrade. If we have a fuel gas with x % carbonic acid, leaving the boilers at the temperature $t°$ Fahrenheit, then the loss of heat in per cent. of that generated on the grate is exactly

$$\text{Percentage loss} = \frac{0{\cdot}3786\ (t-60)}{x}$$

or, in plain words, directly as the specific heat and the temperature, and inversely as the percentage of carbonic acid.

By this formulæ Table I has been calculated, which gives at a glance the percentage loss of heat if the percentage of carbonic acid and the temperature have been ascertained. (Page 44.)

A similar table can be obtained for loss of heat by incomplete combustion. It will be sufficient, however, to say that in ordinary boiler practice, when the gas contains not more than 14 % CO_2 and free oxygen, there is no fear of carbonic oxide escaping with the products of combustion.

A glance at the table shows that a low exit temperature is quite as important as a good analysis. For instance, suppose that a sample of the gases passing into the chimney flue contain 6 % of CO_2 at a temperature of 600° Fahrenheit, the amount of the total heat generated on the grate passing into the chimney would be 34·07 %. If, however, the air admission to the grates were so regulated as to obtain 14 % of CO_2 at this temperature, the chimney loss would be only 14·6 %, or a difference of nearly 20·0 % in the two methods of working the boiler. A loss, I regret to say, is far more common than is generally known.

We may now consider some of the causes which contribute to the loss of efficiency in boilers, as shown by a bad condition of the exit gases and by a high chimney loss. Of course, no "general rule" can be laid down so as to apply to all boilers, for the conditions of draught, heating surface, grate area, type of boiler, and condition of heating surface vary in each particular case, and the amount of fuel which can be burnt per square foot

of grate per hour will depend upon the particular combination of these conditions in each case. Therefore, each boiler installation, even of the same class of boiler, must be tested separately on its own merits. For the moment let it be supposed that the brickwork setting is perfect, the heating surfaces in good and clean condition, and that it is desired to obtain the fair amount of economy as represented by a chimney loss of not exceeeding 15 %. On reference to the tables we require to have the exit gases containing 14 % of CO_2 at a temperature of not exceeding 600° Fahrenheit (or a lower temperature to a lower corresponding CO_2, giving same amount of chimney loss). We may commence with the damper full open, and fire the boilers with fires of a moderate thickness, evenly spread on the grates, taking care that the fire is kept free from holes through which air can too freely pass. If then too low a per cent. of CO_2 is found in the exit gases, the damper may be dropped until the amount of air drawn through the fires is not in excess of that required to produce the required 14 % of CO^2 at 600° Fahrenheit. If, however, it is found that the damper has had to be dropped so low as to unduly restrict the duty—or steaming power of the boiler—our object can be obtained by the use of thicker fires with the damper adjusted at a higher level. In this we have considered a boiler at full duty. Many boilers, however, are required to work at under "full duty." In such cases it is necessary to adjust the damper, and it will often be found necessary to reduce the grate area to prevent the admission of excess air and the corresponding low percentage of CO_2. Many boilers are working under duty with grates large enough to give full duty. The fuel burned per square foot of grate per hour being in some cases as low as 3 to 5 lbs., in which cases as much—and often more—air is drawn through as would support the combustion of 20lbs. per square foot per hour, or four times as much as the proper quantity of air is used.

Let us consider for a moment the effect of this excess air on the efficiency of the boiler, evidently about 80lbs. of air instead of 20 per lb. of coal is being used. This excess air is not generating heat, as there is not fuel enough burned for it to combine with, so it passes into the boiler flues and abstracts heat from the gases, eventually passing to the chimney at the exit temperature. If such exit temperature is taken at 400° Fahrenheit, then for each lb. of coal burned under these conditions there is 60lbs. excess air heated, $(400-60) = 340°$ Fahrenheit, which equals $(340 \times \cdot 378 \times 60) = 7{,}620$ Fahrenheit pound units of heat, or equal to a loss of 55% of the fuel heat in the chimney, or a preventible loss of about 40% of fuel.

This, of course, is an extreme case from actual practice taken for purposes of illustration.

In the above considerations I have taken all the excess air found in the exit gases as having passed the grates. It not infrequently happens, however, that a large amount of the excess air has not passed the grates at all, but has been drawn into the flues through faulty brickwork around the sides and ends of the boiler. This is a very common source of loss. The brickwork, especially of Lancashire boilers, requires continual inspection and attention to prevent such losses. The effect of the contraction and expansion of the boiler shell, often repeated, separates the brickwork from the sides and ends of the boiler, and unless these parts are frequently filled up with mortar, there will be air drawn in which will proportionately increase the chimney loss. In Lancashire boilers, in which the course of the gases are directed from the internal flues first underneath the boiler and finally along the sides, the flue division walls at the back end abut on the end of the boiler. The expansion and contraction of the boiler very soon pushes these walls back, leaving a space varying from a quarter of an inch to three inches between the end of the boiler and the abutment wall. This

passage forms a communication directly with the exit or side flue to the chimney. Now, if it is only considered that the gases will draw to the chimney by the shortest route in preference to first passing along the under flue and then returning by the side flues, it will be seen that a considerable amount of the gases may pass to the chimney direct from the internal flue of the boilers, without first passing under and alongside the boiler at all. This is a common, continuous, and serious cause of loss in such boilers, therefore such partition walls, both at the ends and underneath the boiler, should be carefully inspected, and, if necessary, made tight each time the boiler is off for cleaning. Such losses can usually be detected by the undue high temperature of the exit gases. While speaking of exit gases, it may be mentioned that a frequent cause of high temperature is the dirty or scaled condition of the internal heating surfaces of the boiler. It is well known that scale and dirt are bad conductors of heat, and retard or diminish the rapidity of transmission of heat in a remarkable degree. In consequence, heat is not abstracted from the gases with sufficient rapidity to prevent a too-high temperature and loss at the chimney. A common speed of gas in chimney flues is eight to nine hundred feet per minute. Assuming a Lancashire boiler 30ft. long, the gases travel 90ft. and are about one-tenth of a minute in contact with the heating surfaces; the necessity for a rapid rate of transmission of heat through the plates is therefore very great, and the necessity for clean plates becomes inseparable from economical working. Occasionally it has been found that a high exit temperature accompanies clean surfaces and sound brickwork. On investigation this has been found to be caused by an excessive draught, diminishing the time the gases were in contact with the boiler, or otherwise by an excessive draught supporting a higher rate of combustion than the heating surfaces were able to utilise.

A good deal of difference of opinion exists as to the relative merits of conducting the gases from the internal flues first along the side flues, and finally underneath the boiler, as against the reverse method. Theoretically, so far as a transmission of heat from the gases to the water is concerned, it is right to conduct the gases so that the diminishing temperature of the water and the gases go together. In which case, the gases should be led through the side flues first, because the hottest water is naturally at the top and the coolest at the bottom of the boiler. In practice, however, it is found that this method does not promote such good circulation as in the case where the gases are led below and finally alongside the boiler. It may also be said in favour of the latter plan that horizontal heating surface is more efficient than vertical. This plan is usually adopted in practice and is probably the best.

With reference to the class of instruments required for taking the temperature and analysis of boiler gases.

For taking the temperature there are quite a number of dial gauge thermometers, specially made for reading the temperature of boiler gases. They depend variously upon the expansion of mercury, upon the expansion of air, or of solid metal bars, upon the radiation of light, or upon the resistance to the passage of a current of electricity through heated metal wires. Generally speaking, the mercury, metal, and air thermometers soon get out of order, while the others are too delicate and intricate for portable practical purposes. The writer has found the most useful and trustworthy to be a simple form of Siemen's metal ball pyrometer, which, if carefully used and corrected from time to time, can be relied upon to give sufficiently accurate results, and is perfectly simple and portable. The sample of gases for the test should be drawn just before the gases pass the damper, so as to avoid admixture of any air drawn in about the damper plate. A convenient method is to insert permanently a piece of

iron pipe through the brickwork of the flue arch at this point. Such a pipe will serve for the withdrawal of the sample of gas, and also for the insertion and withdrawal of the pyrometer ball. The ball should be left in the flue at least fifteen minutes to ensure that it is raised to the temperature existing in the flue.

To describe all the various arrangements for sampling the gases would require a paper to itself. Those interested, therefore, may be recommended to look up books on the subject. A good account of such instruments, with illustrations, is given in a book on "Engine and Boiler Testing," by Chas. Day, Wh.Sc., printed by the Technical Publishing Company, Manchester. The apparatus I find most suitable for short tests is the "Orsat" apparatus. It is a portable form, and suitable for the rapid testing of oxygen, carbonic oxide, and carbonic acid. For either long or continuous tests up to three hours, a form of "Stead's" apparatus is found most simple and useful for collecting the gases. Both these kinds of apparatus are described in the above-named book. The writer prefers long tests as being a better check on the firemen, who soon learn to know the "little watchman" will record for or against their ability to fire properly and carefully.

It may not be out of place here to say something about the solid matters deposited in the boiler, which arise from impurities in the feed water, and which often prove a source of serious trouble and loss of efficiency in steam boilers. The impurities in feed water are chiefly:—

1st. Carbonate of Lime.
2nd. ,, ,, Magnesia.
3rd. Sulphate of Lime.
4th. ,, ,, Magnesia.
5th. Chloride of Magnesia.

Carbonate of lime and magnesia are kept in solution by excess of carbonic acid, which latter is driven off when the

water is heated, the carbonate being deposited in a powdery form; and, provided the boiler water is not blown off before the heat is out of the flues, these carbonates will be easily removed as mud. If, however, the boiler is blown off before the plates and flues are cooled down to the temperature of the water, this mud may be baked into a hard scale.

Sulphate of lime is more difficult to deal with, as it deposits at once in the form of a hard scale, making it necessary to use materials in the boiler feed water "anti-incrustators," they are usually named, to decompose the sulphate of lime and cause it to be thrown down in the form of powder or mud. Some form of carbonate of soda is usually found to answer the purpose best. The proper proportions of carbonate of soda required must be fixed in each particular case by an analysis of the feed water.

Chloride of magnesia is, fortunately, not generally present. When it is, "pitting" of the boiler plates always results, due to the formation of hydrochloric acid, arising from the decomposition of the chloride. In this case, also, carbonate of soda will be found a preventive, as it neutralises the acid. A simple way of adding the soda is to dissolve it in the feed water prior to its injection into the boiler. A sufficient quantity will have been added in all cases where the water (sampled at the gauge glass tap) will turn a piece of red litmus paper slightly blue, showing that the water is slightly alkaline.

Stoking and fire-grates is a subject coming within the scope of this paper. The writer is aware this is very debatable ground. His experience with mechanical stoking has led him to the conclusion that except in cases where there are a number of boilers near together, and where mechanical stoking is supplemented by coal elevating and conveying machinery—or otherwise, where the coal can be discharged directly from the wagon into overhead hoppers—there has been no money saved;

and that the expenses for repairs, depreciation, interest, etc., has generally overbalanced any saving in labour or fuel. Apart, however, from considerations of cost, the writer considers that mechanical stoking is correct in principle, because when properly applied it must contribute to maintain a constant supply of fuel and a more regular supply of air, also steadier steaming, and so assist in preventing the large chimney losses already referred to. Very inferior gases are, however, often found leaving boilers fired mechanically. This is sometimes due to the machines being out of order; at other times, due to careless working or adjustment, or to the use of too small or too large an amount of combustion per square foot of grate area in a given time; or neglect in the adjustment of the flue damper, which is a common cause of serious losses both in hand and machine-stoked boilers. For, in each case, there is a certain position of damper for each rate of coal consumption, the area of grate being constant. The writer has seen grates 7ft. 6in. long, with 50 % air spaces, burning 7 to 10 lbs. of coal per square foot of grate per hour, working with dampers full up, and sufficient draught of air to burn 24 to 30 lbs. per square foot of grate. Each steam user must investigate these conditions for himself, and adjust his grates and dampers accordingly. A careful testing and study of the chimney gases will usually put him on the right tack.

Of so-called "Smoke Consumers," there are a large variety. Most of these should be called "smoke disguisers," for many of them admit, in various ways, excess air at the door, dead plate, or at the bridge. Whatever way this excess air is admitted, a reduction of draught takes place due to reduction of vacuum in the flue and the passage of less air through the grates, which reduces the coal consumption or gas generation, while diluting the diminished quantity of gas. The effect is found in the reduction of the steaming power of the boiler, in a lowered

temperature of the gases in the flues, and in the diluted chimney gases assuming a lighter hue. The smoke authorities will be satisfied, but the steam user has undoubtedly had to pay severely for this form of so-called smoke abatement. It has been demonstrated time and again that *black smoke* may be free from carbonic oxide and contain only ¼ to ½ of 1 per cent. of solid carbon. This solid carbon is *really* the matter of contention; but it does not "pollute" the atmosphere in a chemical sense, nor can it as a solid substance be called a "noxious fume." It is, however, unsightly, and forms "smuts," to hide which the steam user is saddled with a loss of fuel heat varying from 10 to 20%—that is, he has to burn 10 to 20% *more fuel* than he would do if allowed to emit concentrated smoke. This 10 to 20% more fuel burned emits a like *extra* volume of "noxious fumes," therefore there is emitted into the atmosphere for a given amount of steam raised *10 to 20% more smoke* with these so-called smoke consumers than without them. We may ask if the smuts of solid carbon have been prevented or consumed after all. The answer must be in the negative, for they have been hidden, but not abolished, and cannot be by the addition of air without extraneous heat. These smuts of solid carbon are formed by the hydro-carbon gas striking the cooler plates of the boiler, depriving the carbon of the heat necessary to effect the complete combustion of the solid element. If a plate is held over a candle flame or a gas jet, it will be demonstrated how these smuts are made, even though there may be plenty of cold or even hot air round about them. If we condense the gases from a boiler chimney, which to all appearance is not emitting "black smoke," because of large dilution of air, we still find the smuts. After all, the question has to be faced: "What are the smoke authorities and their persecutions really effecting?" That they are effecting any ultimate good the writer, for one, entertains grave doubts. Seeing we cannot

reduce the quantily of CO_2 gas given off by the burning of coal, and that it is not one whit more poisonous whether it is black or white, why do not our smoke inspectors leave it alone, and give some attention to that *preventible* and *poisonous* gas "carbonic oxide," and prosecute, where they find that present by analysis of the gas at the chimney; for then some real good might be done both for the purification or sanitation of the atmosphere, and for the steam users themselves, for a very small amount of carbonic oxide gas passing the chimney can not only unnecessarily vitiate the atmosphere, but cause serious loss in undeveloped heat to the steam user.

Studying the question of "Boiler Furnaces" some years ago, the writer came to the conclusion that to really consume the solid carbon in the flame, a furnace must be constructed so as to maintain for a time the initial temperature of the flame, to give time for complete combustion, to obtain which it would be necessary to exclude secondary air.

To combine such a furnace with one that would utilise the heating surface, presented by the grate bars themselves, so arranged as to promote circulation in the boiler, such a furnace (illustrated by photograph) was constructed. The grate consists of water tubes expanded into a box, or header, at each end of the grate. The front header being connected to the water space near bottom of boiler, the back header being connected to the steam space near the water surface level, an under bridge was arranged near to the back end of the grates, and a hanging bridge somewhat behind the back end of the grates. Between these two bridges there is a down draught, which mixes the hot gas drawn through and over the back portion of the fire with the hydrocarbon gas and smuts, passing over the top of the fire, thus effecting combustion underneath the hanging bridge, and before the gases strike the top of the flue again. This arrangement secured all expected from it. The original grate, fitted

over six years ago, has worked continuously night and day ever since, and the writer is informed that it has not cost one penny for repairs or upkeep. There is good circulation, considerable economy, and practically no smoke visible, even immediately after firing, the arrangement forming a combined economiser, circulator, and smoke consumer, along with a permanent grate bar, all its actions being quite automatic. This arrangement secured incidentally other advantages. It was found that the incrustation in the boiler—especially on the top of the flues—was considerably diminished, which is attributed to the better circulation secured. This view is upheld by the fact that there is no deposit whatever inside the tubes forming the grate, where the circulation is much more rapid than it is over the top of the flues. It was found that the clinker did not adhere to the grates, and was much more easily removed than from ordinary grates, a circumstance no doubt due to the grates being kept cooler, thereby preventing the fusing of the clinkers to them; and also to the rounded tube preventing dovetailing of the clinker between the grate bars as with ordinary shaped cast-iron bars. With these bars the water in the boiler is kept at a more uniform temperature, a condition which will considerably reduce the mechanical strains in the shell and flues of the boiler. It is well known that when a boiler is fired up on cold water it is several hours before the water in the bottom of the boiler becomes heated up to the normal temperature, and that to force firing before circulation commences is very dangerous. In this furnace circulation commences almost immediately after firing, and the boiler heats up quite evenly. Experience with these grates goes to show that they will have as long a life as any other part of the boiler.

It may be said that this paper should have dealt more with water tube boilers, but to have done that would have made it much too long. What has been said, however, in con-

nection with firing, testing of gases, excess air, incrustation, etc., applies equally to any kind of boiler. In the writer's experience, with two different types of water tube boilers, he has found that by comparing the tests with similar ones obtained from good Lancashire boilers, there has been no gain in fuel economy, or in cost of upkeep in favour of W. T. boilers, commercial results in every case being in favour of the Lancashire boiler, where moderate pressures (up to, say, 150lbs.) are considered. In the writer's experience, he has seen more serious accidents with W. T. boilers than with Lancashire, where both were under the same management and attendants.

In conclusion, the author hopes that this paper—imperfect as he feels it is—may be the means of arousing more interest in this subject, and so cause others to study the question for themselves, and obtain from the application of the same principles of boiler management the same satisfactory results that have rewarded his own efforts.

Per Cent. Loss of Fuel by Waste Heat in Gases—SLACK.

% CO_2.

Temp. F.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
200°	53·00	26·50	17·66	13·24	10·60	8·83	7·57	6·62	5·88	5·30	4·81	4·41	4·07	3·78	3·53
300°	90·86	45·43	30·28	22·70	18·16	15·14	12·97	11·35	10·09	9·08	8·26	7·57	6·98	6·48	6·05
400°	—	64·36	42·9	32·16	25·74	21·45	18·38	16·08	14·30	12·87	11·70	10·72	9·90	9·19	8·58
500°	—	83·29	55·52	41·64	33·30	27·76	23·79	20·82	18·50	16·65	15·14	13·88	12·81	11·89	11·10
600°	—	—	68·14	51·10	40·88	34·07	29·20	25·55	22·71	20·44	18·58	17·03	15·72	14·60	13·62
700°	—	—	80·75	60·56	48·46	40 38	34·61	30·28	26·91	24·23	22·02	20·19	18·63	17·30	16·15
800°	—	—	93·30	70·02	56·02	46·69	40·01	35·01	31·12	28·01	25·47	23·34	21·54	20·00	18·67
900°	—	—	--	79·48	63·60	53·00	45·42	39·74	35·33	31·80	28·91	26·50	24·46	22·71	21·20
1000°	—	—	—	88·96	71·16	59·31	50·83	44·48	39·53	35·58	32·35	29·65	27·37	25·41	23·72
1100°	—	—	—	98·42	78·74	65·62	56·24	49·21	43·74	39 37	35·79	32·81	30·28	28·12	26·24
1200°	—	—	—	—	86·22	71·93	61·65	53·94	47·94	43·16	39·23	35·96	33·19	30·82	28·77
1300°	—	—	—	—	93·88	78·24	67·05	58·67	52·15	46·94	42·68	39·12	36·10	33·52	31·29
1400°	—	—	—	—	—	84·55	72·46	63·40	56·36	50·73	46·12	42·27	39·02	36·23	33·82
1500°	—	—	—	—	—	90·86	77·87	68·14	60·56	54·51	49·56	45·43	41·93	38·93	36·34

DISCUSSION.

Mr. Sam Boswell said he did not think the days of the rule of thumb were yet passed away, as the author had stated.

It would be interesting to know how Mr. Duff had arrived at his results; they appeared to be rather paradoxical, and it would not be difficult to find results in our own transactions that were entirely opposed to those set down in the paper.

With respect to ash, 12·86 seemed rather too high a percentage, and he (Mr. Boswell) had carried out scores of experiments which showed the average was much lower than that, for ordinary boiler coal with natural draught

The author advocated a low exit temperature, but he (Mr. Boswell) might state that he had recently increased the temperature in the chimney flue about 200 degrees, with the result that 25 per cent. more work had accrued, with the same consumption of fuel, and, in his opinion, a low exit temperature was of less importance than the difference between the temperature in the furnace, and that in the chimney bottom. If there was a low exit temperature they had to burn the fires at a low rate of combustion, and they did not obtain the intense heat required to make an economical arrangement. Wilson, in his book on "Boiler Chimneys." said it was not advisable to have less than from 10 to 12 times the temperature of the atmosphere in the chimney bottom. If there were less than that they were working at a loss.

As to the impossibility of laying down a general rule for all cases, no engineer could state what efficiency would be obtained from any boiler which was being put down, as so many things had to be taken into consideration, and the rule of thumb had, in a measure, to be resorted to, in the construction and making of a boiler.

With respect to having the heating surface clean, this was a difficult matter. Deposit would necessarily be in the boiler, and he did not always attach so much importance to keeping it clean.

Regarding dampers, it was a wrong thing to have them half open at any time, as suggested by the author. If the damper was full open, and they were burning too much coal, and making too much steam, they should shorten the grates, and limit the amount of air going through, and not move the damper down. He could not see how a boiler would be considered at full duty with the damper half open. The author mentioned 8 to 5lbs. of coal per square foot of grate per hour. He questioned whether it was possible to keep a boiler doing useful work with only that amount, and he had never known a case like it.

He had not found that Lancashire boilers required the continual attention and inspection which the author said they did. The Lancashire boiler was one of the easiest to keep right, and he had never seen a case where the brickwork got away to the extent of three inches, except at a chemical works, and where it was certainly no fault of the boiler or at all due to expansion.

The statement in the paper as to scale and dirt retarding the transmission of heat required some qualification, and he could show the author solid sulphate of lime ½in. thick, taken from boilers, which only did the same duty when cleaned as when the scale was on.

The author told them that the velocity of the gases in the chimney was eight to nine hundred feet per minute; how was that result obtained? The last time he (Mr. Boswell) had used the anemometer he put it in three different places, and could obtain almost any result desired over a prolonged test; he obtained 420, 650, and 800, and that was as high a velocity as he could get with a keen natural draught.

Again, he did not think that clean plates were an absolute necessity for economical working. Some of the Oldham cotton mills were giving better results than any other mills in the country, and yet the boilers, owing to a want of purer feed water, were as dirty as anyone could wish to find; and further, he did not think there could be an excessive draught with a natural draught. A natural draught could not be too keen. If the draught were too strong for the boilers, the grates should be shortened and thicker fires burned.

As to the course of the draught underneath the boiler, the author appeared to favour one particular method; he (the speaker) had never yet been able to say which was the best. The author's theoretical reasoning was all right, if they let the feed water go in at the boiler bottom. The water, however, usually went in near the water level, and did not get much cooler at the bottom than at the top, owing to the circulation in the boiler. The difference in temperature between the top and the bottom was inappreciable when once they got working.

The best test of the economical working of a boiler was the monthly coal bills, which enabled them to readily see what they were doing.

The author had stated that carbonate of lime would bake hard, if the boiler were blown off before the plates and flues were cooled to the temperature of the water. This, in his opinion, would never occur. As to sulphate of lime depositing a hard scale, this was so, but it was far less dangerous than floury deposit of carbonate of lime and magnesia, which was responsible for the collapse of more furnaces than almost any other cause. A scale of sulphate of lime was not injurious in any way whatever, and he had a number of samples of sulphate of lime which had been in boilers, and which made no difference at all in the working.

With regard to "pitting" due to chloride of magnesia, it did not follow that the elements that caused pitting were always, and of necessity, present in chloride of magnesia, and the statement required qualification. As to drawing the samples of water from the gauge glass tap, they might get the litmus paper as blue as could be, but taking the water from other parts the paper would turn red.

He did not agree with the statement that there was a certain position of damper for each rate of coal consumption; the only proper position for the damper when in full work was wide open. As to grates burning 7 to 10lbs. of coal per square foot, he might mention a case of a paper mill where they were burning 9lbs of coal per square foot with seven boilers, but complained of lack of boiler power. After examining the plant he told them that all they needed was a chimney. This was put in, and, by running the coal consumption up from 9 to 16lbs. they were enabled to knock off two boilers out of six. In another case the consumption was increased from 11 to 28lbs. per foot, and the weekly coal consumption was reduced from 11 tons to 5 tons, by simply shortening the grates and having the dampers wide open.

He concurred with the author in the remarks on smoke-disguisers.

As to carbon smuts was it not a fact that these were highly charged with sulphur, which caused all the trouble?

It would be interesting to know what work the author was doing with the special furnace he had illustrated, but he (Mr. Boswell) failed to see how any benefit could be obtained from the tubes, seeing that the cold air had to strike them before the heated fire came into contact with them, and the absence of deposit could only prove the small amount of work done in the boiler.

Mr. T. WALTON observed that although Mr. Duff in the earlier part of his paper deals with the composition of chimney gases, with varying conditions of stoking, good and bad, etc., there was one condition not mentioned, viz., furnace capacity. He would like Mr. Duff to say if he had found per chimney gases a more perfect combustion in furnaces of large diameter, where the gases had room to combine with air admitted through and over fire, and ignite before leaving the hot region of the fire; had he found better results in these cases than in small furnaces, where the rate of consumption per foot of grate has been about the same?

Respecting smoke prevention, he had very little faith in secondary combustion, or arrangements for consuming the smoke after it had left the furnace. If gases were not sufficiently supplied with oxygen, to be consumed in the furnace, there was only a small chance of them being consumed in the comparatively cool flue tubes, as Mr. Duff says they can be thinned, for although they may be supplied with air behind the bridge, there must be some incandescent or highly heated substance or flame to ignite the mixed gases. This had been attempted by various descriptions of bridges, tiles, etc., but although these might be incandescent when fires were at their best, as the fires cooled down before re-firing, the bridges, tiles, etc., cooled also. Again, there was still further cooling when the door was opened some 30 or 40 seconds for the introduction of a fresh charge of cold and often wet fuel, which still further reduced the temperature of furnace and surroundings.

Some 10 or 12 years ago he saw a smoke-consuming furnace attached to a Lancashire boiler, in which the firebars were set up at an angle of about 45° in a furnace built against the boiler front, the lower ends of bars just entering the flue tube. The inventor's or patentee's idea was to retain the furnaces at a high temperature, and so obtain complete combustion of fuel before

its temperature could be reduced by coming in contact with the comparatively cool boiler. He could not say how far this class of furnace succeeded, but would like Mr. Duff's opinion regarding the maintaining of a very high temperature in furnace, by protecting same from the cooling effects of the boiler. Did he think a more complete combustion could be obtained by these means without risk of burning furnace plates?

On page 40 Mr. Duff asked the question, "What are the smoke authorities and their persecutions really effecting?" There was a somewhat clearer atmosphere; but was it more pure? From his experience he thought not. Black smoke could be seen, and was not pleasing to the artistic eye; carbonic oxide was not seen but felt by its effects. People did not know where it came from, and consequently did not grumble at the chimneys because they could not see it. Some little time ago he required a new top or blocking on a chimney about 50yds. high. This chimney was not to be allowed to smoke on any account, although it had to discharge the gases from three boilers, consuming about 50 tons of coal per 56 working hours. The bricksetter that built the new top had to give up the job in working hours and wait until Saturday afternoon, although three weeks previously he had done a similar job on a notoriously smoky chimney without any difficulty.

Mr. R. Brown said if they had not more than 1 to 2% of oxygen in the exit gases they were burning the fuel with good results.

Mr. Henry Webb, dealing with the question of mechanical stokers, said he was connected with two mills, which had eight boilers. A most complete system of mechanical stokers, coal elevators, hoppers, &c., was adopted, costing £4,000. Notwithstanding this 30 tons more coal was burned per week than with

hand firing, and there was also considerable expense in repairs, &c., to the plant. The result was that at the end of twelve months they reverted to hand firing.

Mr. THOMAS ASHBURY, in moving a vote of thanks to Mr. Duff for his interesting address, observed that very considerable results had recently been obtained with water-tube boilers. The boilers on the warship "Terrible" had given results which had certainly upset some of the theories held by the opponents of water-tube boilers. It would not be right to condemn them simply because they were new.

It would come as a surprise to those who had been able to inspect the boilers mentioned by Mr. Webb to hear that the apparatus had proved so absolutely a failure.

One of our leading engineers had observed that the very best stoker to be obtained was a good, conscientious fireman, and certainly a good fireman frequently secured results that beat all theories.

Mr. JOHN TAYLOR, in seconding the motion, said he had never found such bad examples of boiler-setting as those referred to by the author.

As to smoke-consumption, he had seen one or two mechanical appliances that answered fairly well, but immediately the conditions of working were changed they became practically useless. In Fairbarn's time this question came to the front, and as a result of the movement the system of side firing in boiler furnaces was started. By this method one side was fired at once, care being taken not to make it too heavy, but to leave the centre of the fire with sufficient activity in it to ignite the smoke when it came off. This system produced the best results, but required a sensible man to do the firing. If they adopted side-firing,

with a free burning coal, and did not give the fireman too much work to do, very little black smoke would be produced.

He did not believe they could have too much draught. They simply wanted just sufficient grate-surface and no more, and should admit as much air as was necessary for active combustion, but must not go beyond this amount.

As to deposit in boilers, he had come across one case where the boilers had been working 33 years, and were covered at the bottom with a deposit 3 to 5in. thick, without any collapse or explosion happening. Under any circumstances the deposit in a boiler was not altogether so injurious as was stated, in lessening the safety of a boiler, or in preventing the generation of steam. It was desirable to keep a boiler clean, but too much trouble should not be taken. Caustic soda had been used in many cases to prevent deposit, but it cost nearly as much as the coal.

He had suggested in Oldham that in order to overcome the smoke difficulty a committee should be formed, and independent people appointed to thoroughly investigate the matter, so as to ascertain what was the best class of coal to use, and whether mechanical stoking was better than hand-firing, &c., but they would not find the money necessary to carry out the above plan. It was ridiculous for the authorities to fix a limit of time for making smoke; they had no right to do this. If a man burnt coal he would have to make smoke.

Mr. W. Bayliss said the author spoke of burning 3 to 5 and 7 to 10lb. of coal per square foot of grate, but in Lancashire it had been found that 20 to 25lbs. was the most economical amount.

The author spoke of having very low temperatures in the final gases. Seeing that in Lancashire it had been found that about 20 to 25lbs. of coal per square foot of grate was the best amount

to burn, how did the author, when going in for low temperatures, get a natural draught, sufficient to burn 25lbs. of coal, with his damper half-closed? Also, how low temperatures were to be obtained without the introduction of extra heating surface (such as economisers), with which all modern economical boiler plants are fitted, and of which the author has made no mention?

He should like to know what length of grate the author found to be capable of being most economically fired, and also how a small diameter of furnace compared with one of larger diameter for efficiency of combustion.

Mr. DUFF, in responding to the vote of thanks, said with regard to Mr. Boswell's comments he could not see in what respect his results were paradoxical. The 12·86 % of ash was obtained by trials with a very large number of slacks supplied to works, and the analysis had been made by an eminent chemist. If a high exit temperature was preferable to a low one, he should like to know why people used economisers to lower the temperature. He still maintained that the position of the damper should be regulated according to the work being done.

He was sorry to say he had seen a great number of boilers working with 3 to 5lbs. of coal per square foot of grate, some with very low chimneys and large grates, and the fires were simply burning and that was all. By making the consumption more in accordance with the height of the chimney and the area of the grates, a considerable economy had in many cases been effected. As to the brickwork of boilers, he had known this to get pushed back as much as five inches. If the water was as hot at the bottom of a boiler as at the top, as Mr. Boswell had stated, there would be very little circulation. Mr. Boswell's statement that carbonate of lime would cause the flues to collapse, but that any amount of sulphate would not, was not

in accordance with his (the speaker's) experience. He might add that if a piece of scale dropped on to a boiler tube, which was above the fire, the tube would burn out where that sulphate alighted, owing to the non-conductivity of the sulphate.

Referring to Mr. Boswell's numerous "opinions" refuting the results of the tests in the paper, he might say that he submitted them to the Association as matters of fact, obtained by careful investigation in practical testing work, against which those "opinions" must stand as such. He would be satisfied by saying that if Mr. Boswell would take to accurate observation and measurement by testing, and discard the rule of thumb and opinion method, he would soon be forced to reverse most of the opinions and statements he had made.

In answer to Mr. Walton, he should think, judging from what he had observed, that the larger the furnace the better would be the consumption of the chimney gases. With regard to having the furnace separate from the boiler, better combustion could be obtained, but the radiation from the brickwork more than counterbalanced this advantage.

The case of a man being able to work on a smoky chimney and not on a non-smoky chimney might be due to a difference—which need only be very slight—in the amount of carbonic oxide coming from the tops of the respective chimneys. He quite agreed with Mr. Brown's statement as to the amount of free oxygen in the gases that was sufficient for free combustion.

When he talked of the duty of a boiler he referred to what it was able to produce under any given condition, and this necessarily varied according to circumstances.

As to water-tube boilers he had simply referred to the results of his own experience with two of them, which gave no better results than ordinary Lancashire boilers, but there were many types of which he could not speak, as he had had no experience of them.

Caustic soda was now much cheaper than it was at the time mentioned by Mr. Taylor.

He had only pointed out the use of 8 to 5lbs. of coal per square foot of grate as abnormal, and not as a practice to be imitated. He had not said anything about getting natural draught with dampers half down; he had simply said that the damper should be adjusted according to the work being done.

In conclusion, he thanked the members heartily for their vote of thanks, and need only add that he had thought it would be of some little interest to give them the results of his experience in connection with methods of obtaining increased boiler efficiency, which had proved of the greatest value to himself.

TRANSMISSION OF HEAT THROUGH SURFACES.

READ SATURDAY, 27TH FEBRUARY, 1897,

BY

MR. O. M. ROW,

MANCHESTER.

The title given in the syllabus to this paper has such a wide scope that it becomes necessary to refer but briefly to the various points mentioned in the synopsis, only in a practical way, and in the hope that the combined remarks and the discussion which will ensue may prove of interest to some of the members. No attempt will be made to be scientific, nor to enter into tabulations that are only obtainable by men who are devoted solely to such refinements in calculations, but to deal principally with the question of generating and using steam. This will be admitted by all to be the most important agent there is in the conversion of heat into work, and an evidence of its recognised value is the extreme care exhibited by our best engineers in its use, and the great variety of appliances which have in recent years come before steam users with a view to economising. The old adage "Time is money" might safely be modified to "Steam is money," and yet the waste that is witnessed around us would lead one to think that it cost nothing and that it was valueless.

The first consideration should be boilers, but this is a subject which was ably dealt with by Mr. Duff, and discussed by the members at the meeting on the 23rd of January, so that it shall

only be referred to very briefly. It having been stated that scale was practically no detriment to the transmission of heat, the introduction of a few figures bearing on this point will be interesting, and certainly, if they are false, should not go unchallenged. They appear in Clarke's *Treatise on Engines and Boilers.*

Extract from a Paper read in Manchester, February 23rd, 1858, by Mr. John Graham, before the Literary and Philosophical Society:—

"The following are the proportions of water evaporated per pound of coal under various conditions:—

	Water from 50 deg. Fah. per lb. of coal.	From and at 212 deg.
"When in a dirty condition within, with a slight scale of sulphate of lime about the thickness of a sixpence or less; in other respects under ordinary circumstances, with a 7in. fire	5·50	6·26
"When made perfectly clean internally, with a 7in. fire	6·45	7·34

Showing that a scale of sulphate of lime $\frac{1}{16}$in. thick reduced the efficiency 14·7 per cent.

It will probably be of interest to notice a special form of boiler in use with great success at a leading brewery in Dublin. A few of the particulars are as follows:—

These boilers are of the horizontal type with two flues working with artificial draught and hot air. There is no brick-setting which is common to the fixing of the ordinary Lancashire boiler. The boilers are well lagged; the waste gas from the furnaces is utilised by raising the ingoing air to a high temperature for the purpose of better combustion in the furnaces. The heating surface in each boiler is 1,350 square feet; the heating surface exposed as an air heater to each boiler is 1,110 square feet; the quantity of water evaporated is 9,300lbs. per hour, at 100lbs.

pressure, from a temperature of 180° Fah., being 11·2lbs. of water evaporated from and at 212° Fah. per pound of pure and dry coal; the temperature of the gases in the smoke box after leaving the boiler 600° Fah.; the temperature of the heated air passing to the furnaces is 350° Fah., but owing to leakage in the construction of the casing it is calculated that only two-thirds of the air used in the furnaces is passed through the air heater. These results appear to be highly satisfactory, and should be of interest to members interested in steam boilers.

Having reference to Water Tube Boilers, the experimental boiler here produced and illustrated on Plate 8 has been made with a view to demonstrating the circulation in the tubes. A considerable amount of controversy has been going on for some time as to the necessity for outside down pipes for the return circulation, and by observing the behaviour of the tubes in the model boiler it will be seen that the circulation and the evaporative efficiency of the tubes is quite as good without the outside down pipe. The boiler has been so arranged that it can be worked either way, by means of the coupling pipe and cock A and B, Plate 8, and a group of tubes of this character agree among themselves and settle without outside assistance which shall be the up-takes and which the down-takes, the majority of the tubes taking the upward current and a small minority taking the downward current. Naturally the tubes taking the upward current are those most nearly exposed to the action of the flame.

Following are two tables extracted from Seaton & Rounthwaite's Pocket Book on Marine Engineering, being performances of Torpedo Boat machinery obtained by Messrs. Thornycroft & Co. and Messrs. Yarrow & Co. These are included as interesting references.

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TABLE LXIIIa.—PERFORMANCE OF TORPEDO BOAT MACHINERY. (Messrs. THORNYCROFT & CO.)

Type of Engine.	A	Equivalent Values	Double Compound.							Triple Compound.					
Ratio of Cylinders.	B		1 : 2·68					1 : 2·8		1 : 2·04 : 5·05					1 : 1·96 : 4·84
Coal per foot of grate per hour.	C	$\frac{IJ}{F}$ $\frac{F}{D}$	69·3	87·5	95·2	97·2	82			45·4	40·7	43·75	66·2	74·1	
Water per lb. of coal from and at 212°.	D	$\frac{F}{C}$	7·7	7·65	7·61	7·54	7·6			9·77	9·95	9·81	8·82	8·55	
Ditto, Steam from 100°.	E	$\frac{N}{I}$	6·64	6·58	6·54	6·48	6·55			8·35	8·5	8·39	7·37	7·11	
Water per foot of grate per hour from and at 212°.	F	CD	533	670	724	732	623			443	406	429	585	633	
Ditto, Steam from 100°.	G	$\frac{NJ}{CE}$	460	576	622	630	536			379	346	367	488	527	
Steam pressure.	H	..	120	120	120	120	130			200	200	200	250	250	
Pounds of coal per I.H.P. per hour.	I	$\frac{C}{J}$	3·92	3·95	3·98	3·98	3·94			2·12	1·98	2·02	2·44	2·77	
I.H.P. per foot of grate.	J	$\frac{L}{K}$ $\frac{C}{I}$	17·7	22·13	23·95	24·42	20·8			21·46	20·54	21·64	27·11	26·73	
Square feet of heating surface per I.H.P.	K	$\frac{L}{J}$	1·78	1·43	1·32	1·29	1·82			2·82	2·95	2·8	2·12	2·15	
Square feet of heating surface per foot grate.	L	KJ	31·6	31·6	31·6	31·6	37·9			60·53	60·53	60·53	57·46	57·46	
Air pressure in inches of water.	M	..	3	5	5	5·5	3·2			2·1	1·7	1·3	2·6	3·5	
Pounds of steam per I.H.P. per hour.	N	$\frac{IE}{J}$ $\frac{G}{J}$	26	26	26	25·75	25·75			17·65	16·8	16·9	18	19·7	
Type of Boiler.	O	..	Locomotive Type.							Thornycroft Water Tube.					
Distinguishing number of Engine.	P	..	1	1	2	2	3			4	5	6	7	8	
Description of Vessel.	Q	..	First-class Torpedo Boats.												

TABLE LXIIIb.—Messrs. YARROW'S STANDARD TORPEDO BOAT PRACTICE.

		1st Class Torpedo Boat.	2nd Class Torpedo Boat.
Standard Sizes	Length ..	130 feet.	60 feet.
	Breadth ..	13 feet 6 inches.	9 feet 3 inches.
Displacement		85 to 90 tons.	About 16 tons.
Load carried		25 tons.	4 tons.
Average Speed	Triple Engines	23 to 23¼ knots.	About 17¼ knots.
	Quadruple „	Up to 24½ knots.	———
Type of Engine ..		Inverted triple surface condensing, three-crank; or quadruple four-crank.	Inverted triple surface condensing three crank.
Cylinders and Stroke	Triple	14½in.—21in.—32in. / 16in. stroke.	8in.—12in.—17½in. / 9in. stroke.
	Quadruple	14in.—20in.—27in.—36in. / 16in. stroke.	———
Ratios of Cylinders	Triple	1 : 2·09 : 4·87.	1 : 2·25 : 4·78.
	Quadruple	1 : 2·04 : 3·72 : 6·61.	———
Type of Boiler.. ..		By preference Locomotive type for durability and easy access; but Water-tube boilers of "Yarrow" type* when high trial trip speed is first consideration.	
Boiler pressure	Triple	160 to 180 lbs.	160 to 180 lbs.
	Quadruple	200 to 220 lbs.	———
Air pressure		Average under three inches, but occasionally as high as five inches.	
Coal burned per square foot of grate per hour		60 to 100 lbs.	
Heating surface per square foot of grate		With Locomotive Boilers 45 to 50 square feet.	
Revolutions per miuute at full power	Triple	About 410.	About 560.
	Quadruple	About 435.	——
I.H.P. per square foot of grate		Triple Engines and Locomotive Boilers, 35 to 38 I.H.P. Quadruple Engines and Locomotive Boilers, 37 and 40 I.H.P.	

* When water tube boilers of the "Yarrow" type are used, the grate bar area and heating surface obtained are about 50% greater than with Locomotive type boilers, and the quantity of coal burned per square foot of grate is much reduced.

Referring now to the transmission of heat in steam pipes, and the consequent condensation,—the following table shows the amount of condensation which took place in an actual test at different pressures per square foot of steam pipe exposed to the open atmosphere at 70° Fah. :—

Steam pressure	0	5	10	20	30	40	50	60	70	80	90	100
Condensation in lbs. per hour as per test	·73	·94	1·0	1·06	1·17	1·36	1·46	1·55	1·63	1·69	1·76	1·84

This not only represents a loss in value of steam, but becomes a serious annoyance and expense in many ways. Of course the wise thing is to resort to good lagging, but even that is not a perfect preventative, owing to the exposure of joint ends, &c. Having made enquiries as to the value of lagging, the writer has been furnished with a table of a test made with four different makes of non-conducting composition. The pressure of steam in the pipes was 80lbs. per square inch. In all instances the covering was 2½in. thick, and the temperature registered with thermometer placed on the top of the pipes and protected from the air currents was, respectively, as follows, viz., 110, 119 123 and 139° Fah. It might perhaps be stated that the best efficiency, viz., 110° Fah. was obtained by the lagging of a local firm. The practice generally adopted for pressures of a low character, say up to 40lbs., is for the pipes to be covered with lagging 2in. thick, for pressures up to 80lbs. 2½in. thick, and beyond this 3in. thick; and perhaps for the very high pressures of practice a little thicker than this would be necessary. The same rule will apply to cylinder casings.

A very good way of capturing the condensation is to have a slight gradient in the pipes, and at the lowest point fix a receiver and steam trap, as shown on Plate 1, Fig, 1. This

arrangement is also very convenient to receive condensation from cylinders to prevent hammering. See Plate 1, Fig. 2.

Now referring to surface condensation, the following are the results of a very interesting experiment made by Mr. B. G. Nichol, of Newcastle-on-Tyne, an account of which is given in *Clarke's Rules, Tables and Data* (D. K. Clarke). The tests consisted as follows:—

A brass tube $\frac{3}{4}$in. in diameter, No. 18's wire gauge, was enclosed in an iron pipe $3\frac{3}{4}$in. in diameter outside, and 5ft. $5\frac{1}{2}$in. long between the ends. The brass tube exposed an external surface of 1·06 square feet. Steam was admitted into the annular space in the iron pipe around the brass tube, and was condensed by cold water passing through the brass tube. The iron pipe was lagged on the outside to prevent radiation of heat in that direction, so as to throw the whole of the work of condensation on the surface of the brass tube. The temperature of steam introduced for experiment into the pipe was 255° Fah., and the initial temperature of the condensing water was 58° Fah.

For the purpose of comparison, a piece of brass tube of the precise dimensions given in the above test was taken and indented so as to form an impinging surface, and was tried vertically and then horizontally, in a precisely similar condition to the tests made with the plain tube, and the following are the comparative results:—

	Vertical Position.			Horizontal Position.		
	1,	2,	3.	4,	5,	6.
	Steam condensed per square foot of tube per hour.					
Plain.....	52·32,	78·18,	84·34.	67·8,	104·6,	121·3 pounds.
Indented..	171·0.	—	—	167·4.	—	—
	Condensing water per pound of steam condensed.					
Plain.....	12·6,	29,	37·7.	9·3,	24,	27·9 pounds.
Indented..	8·4	—	—	7·7.	—	—

The further tests were not made with the indented tube, for the reason that the necessary quantity of cooling water was not available.

The usual marine practice of proportioning the cooling surface in surface condensers is as follows :—

For Modern Mercantile Triple Engines, 1·8 sq. ft. per I.H.P.
,, Naval Engines, 1·1 ,, ,,

The proportion of cooling water in these latitudes is 24 to 30 pounds to one pound of condensation.

The subject of Evaporative Condensation is one of interest, and has come into more particular prominence within the last few years, more particularly in localities where there is not available a plentiful supply of water suitable for cooling in an ordinary surface or jet condenser. In this type of apparatus condensation is obtained by transmitting sufficient heat from the steam to the small quantity of water being trickled over the surfaces, so as to cause a new vapour on the outside of the condensing tubes which carries off not only the apparent but the latent heat of the steam being condensed. By this means, as will be seen from the following tables, a perfect condensation and a good vacuum can be obtained (of course always depending upon an efficient air pump) and using only a quantity of cooling water less than the amount of steam being condensed; and in an efficient apparatus of this type engines can be worked on the condensing principle and really economise the use of water to a very considerable percentage as compared with the use of water for feed purposes only if the engines were non-condensing; so it will be seen that in central power stations it is particularly adaptable. The writer has, preferably, made experiments with copper tubes for the reason that the high conductivity of copper is a great advantage in this type of apparatus; it allows of the installation being much more compact and light, and from the

table of experiments following will be seen the ratio of efficiency of plain copper tube as compared with indented tubes, and then again a third test showing the value of a directed air current in addition to the trickling water. Figs. 1 and 2 on Plate 2 give precise representations of the experimental apparatus used with indented tube without and with air current. The plain tube test was conducted with the tube of Fig. 2 before being indented. The operation is indicated by the reference letters. The steam was admitted into the tube at Valve A, condensation dropping into receiver B and vacuum induced by ejector C, condensation being drawn off at stated periods at cock D. The cooling water was raised to the top of tube by pump E, and allowed to trickle in a thin film from pan F; the water not evaporated fell into receivers G and G^1, and was repumped.

Test as per Fig. 2 was conducted in a precisely similar way with the addition of casing H, through which an air current was induced by the exhaust from ejector being discharged into branch J.

Evaporative Condensation.

TEST.

See Plate 2, Figs. 1 and 2.

The plain tube used in No. 1 Test was 16ft. 0in. long × 1¼in. bore and 16 L.S.W.G. thick. This was afterwards indented for tests Nos. 2 and 3, and then measured 14ft. 5¾in. long. The total condensing surface exposed to the atmosphere was 8 square feet including surface in the pan G and receiver B.

Considerable difficulty is being experienced in the use of plain tubes to completely cover the surface with the thin film of water. The tendency is for the water to run down in rivulets, leaving a considerable portion of the surface exposed to air contact only. By the experimental apparatus on the table it will be seen that the indented tube is very evenly covered by the film, while

the plain tube shows a tendency to form the rivulets above referred to.

Description of Test.	No. 1. Plain Tube and Condensing Water only.	No. 2. Indented Tube and Condensing Water only.	No. 3. Indented Tube and Condensing Water, assisted with Air Current.
Time, one hour { Commencement ..	10-45	12-0	3-0
Time, one hour { Finish	11-45	1-0	4-0
Temperature in Receivers, G and G1	133° Fah.	120° Fah.	115° Fah.
Quantity of Condensation	20·62lbs.	39·69lbs.	63·4lbs.
Temperature of Atmosphere	65° Fah.	70° Fah.	64° Fah.
Vacuum	10lbs.	10lbs.	10lbs.
Temperature of Condensation at D ..	154° Fah.	155° Fah.	153° Fah.
Quantity evaporated	10·62lbs.	27·0lbs.	50lbs.
Condition of Atmosphere	Gentle Breeze.	No Wind, Fine, Warm	Dull, Windy.
Date	July 3rd, 1896.	July 6th, 1896.	July 27th, 1896.

On the basis of these tests with air current, and knocking off 25 % of the results obtained under experiment, and taking the condensing efficiency of indented copper tube as equalling six pounds per hour per square foot of surface, it is possible for an Evaporative Condenser, suitable for 200 HP, allowing 20lbs. of feed per IHP, to be enclosed in a casing of 3ft. 6in. square, standing 12ft. high, and as the air current is carried to these tubes by means of a fan it is not necessary to erect the condensing apparatus in a high and exposed place, but it may be placed anywhere in the vicinity of the engine room, and a vapour pipe carried from the top to any suitable position. Plate 3 gives a representation of a complete condensing plant as designed for 200 IHP engine. The vapour carried off

from this apparatus may be condensed and become a valuable quantity of pure distilled water, for use as feed make-up or other purposes.

The subject of evaporation for feed make-up purposes has not received much attention on land, but in districts where feed water of a bad quality exists it is well worthy of engineers consideration. These particular appliances have been more sought after in marine practice, and it may be fairly claimed that the marine engineer is more careful of the condition of his appliances than is the usual practice on land—perhaps more by compulsion than anything else. Still the fact exists. The results are given of an experiment carried out with the plain tube, and an indented tube, in the following table, and the experimental apparatus illustrated on Plate 4, Fig. 1, showing plain tube in position, which was afterwards indented as Fig. 2 and replaced in position.

Evaporator Test.

Description of Test.	No. 1 with plain Tube.	No. 2 with same Tube as in No. 1, but indented.
Area of heating surface in Tube..	1 square foot.	1 square foot.
Quantity of water in casing	11 gallons.	11 gallons.
Temperature of water at start ..	42° Fah.	42° Fah.
Time taken to raise to boiling point	11 minutes.	5½ minutes.
Time taken to evaporate 12in. on gauge = 2½ gallons.....	24 minutes.	11¾ minutes.
Steam pressure	62lbs.	62lbs.

The usual practice with an apparatus of this kind is to obtain steam from the main boilers, or after being used in one or more of the engine cylinders, for heating the water to be evaporated and the draining of condensation of such steam back into the hot well for re-use as feed. The vapour generated in the

evaporator is then easily conveyed to the hot well for condensation and mixing with the feed water, by which means all the units of heat are absorbed, or in some cases it is led direct to the surface condenser. This latter practice, however, is not advisable, as the units of heat extracted in the process of condensation are carried away by the circulating or cooling water. A better practice however which might be adopted with benefit would be to pass the new vapour from the evaporator through a feed heater, such heater to be fixed between the feed pumps and the boilers. Then the feed pump would not be troubled with pumping water at a high temperature, and the final heating would be done after it had passed the pump; the residue of vapour could then be mixed with the water in the hot well, and the condensation taking place in the heater carried to the same place. In that way all the heat would be got and the pumps allowed to work in an easy way. Such evaporators have to be designed with a view to the easy withdrawal of the heating tubes for cleaning purposes, and any form of tube that will readily cast its scale is advantageous. See Fig. 2, Plate 9.

Having reference to the frequent waste of exhaust steam, it is surprising that more care is not exercised. It is assumed by some folk that the planet Mars is inhabited, and if any of the inhabitants of that somewhat remote sphere were taking observations of this earth, particularly these Islands, there would be some very strong remarks in their log book referring to the extravagance of steam users both on the question of exhaust steam and smoke. Wherever one goes one sees exhaust steam blowing to waste to an inordinate degree. It is a matter deserving more attention than it at present receives. Of course heating the feed water by exhaust steam does not use up all the steam by any means—in fact, a simple calculation of the units of heat contained in the exhaust and the units put into the feed water to raise it to about 200° Fah. would show that about one-

seventh of the total amount only is absorbed in this way, but then in many manufactories there are innumerable important uses for hot water, and the exhaust might be further utilised for these. With regard to the question of feed water heating, utilising exhaust steam, it can be clearly shewn that an economy in the use of fuel from 13 to 15 per cent. is obtainable, and in addition to the economy in fuel, a very important point, which is too often overlooked, is the improved condition of the boilers, due to hot feed being used instead of cold. We sometimes see old boilers or tanks used for storing feed water into which the exhaust steam is blown. This practice is subject to the objections that it mixes the lubricants from the engine cylinders with the feed and runs the risk of such grease being pumped into the boilers which somtimes troubles the feed pump by its high temperature. The most desirable practice is for a surface feed heater to be placed on the line of feed pipe between the pump and the boilers.

For the value of different surfaces for heating feed water refer to Plate 5, Figs. 1 and 2, showing test of a plain tube and an indented tube, and the results are given in table as follows :—

Description of Test.	Plain Tube as Fig. 1.	Indented Tube as Fig. 2.
Temperature of steam to tubes.	212° Fah.	212° Fah.
Temperature of water at start..	48° Fah.	45° Fah.
Quantity of water in casing ..	21 gallons.	21 gallons.
Quantity of surface in tube...	1 square foot.	1 square foot.
Time to heat to 180° Fah. at thermometer	106 minutes.	58 minutes.

This test is with steam through the tubes, but an equal efficiency is obtained with the water through the tubes.

With certain water there is a tendency to deposit scale, in which case the exhaust steam should be put through the indented

tubes and the feed water carried over the outer surface of the tubes, and here uneven or indented surface shows a value in throwing off scale (see sample), but where good water is being dealt with the order is reversed and the feed water pumped down through the tubes, allowing the exhaust steam to play upon the outer surface of the tubes, in a suitable casing.

A point of controversy in engineering circles is whether a live steam heater is an economiser of fuel. All that can be said on this point is that experience is distinctly in favour of live steam heating where exhaust steam is not available rather than use the feed at hot-well temperature. By this means a distinct economy of fuel is effected, easier steaming of the boilers, and troubles that previously existed in the way of leaky bottom seams or tube ends have been totally avoided. In *Engineering* for January 29th, 1897, is given an article on "Feed Heating" of a most valuable character, in view of the system having been adopted with a set of condensing engines (indicating 635 HP). The heating of the feed water in the heater is done by steam from the low pressed receiver. In this receiver the steam has a temperature of about 239° Fah. (115° Cent.), and it is thus but a question of heating surface to get the feed heated up to boiling point. The heater had a total surface of 200 square feet. The water was heated up to boiling point. When the engines worked without the heater the feed water was pumped into the boilers at a temperature of 111° Fah, (44° Cent.). The profit through heating up the feed amounted to *9·18 per cent.* It is strongly advised that members should read this article on feed heating, where all the details are given, with which it is not now necessary to deal. Looking at the point commercially, the following report from a source unbiassed in any way is of interest. "The actual saving in hard cash effected by the use of feed water heater worked with live steam is undoubtedly well over 10 per cent., and as far as I have been able to calculate at

present, seems to approximate 15 per cent., the exact figure being governed by the closeness to its maximum duty at which the boiler is being worked."

The writer has had an opportunity of seeing the effect of live steam heaters in torpedo boat practice, in two or three instances where it was found impossible to maintain the requisite speed on trials without a feed heater owing to the difficulty of maintaining the steam even with the most experienced firing, and where a live steam heater has been fixed the difficulty has been overcome in the most satisfactory way. Other instances of similar work could be given were it necessary.

The proportion of indented tube surface in practice for live steam feed water heating is 1·5 square feet per 1,000lbs. of feed per hour heated from 100° Fah. (the temperature of the hot well) to 212° Fah., and it must be admitted that feed water entering the boilers at 212° Fah. instead of at 100° Fah. is good practice. For illustration of a Marine Type Live Steam Feed Heater, see Plate 10, Fig. 1.

Another interesting test is in the steam heating of water for circulation through pipes and radiators for warming buildings on what is known as the low-pressure hot water system, and this is now more generally recognised as the best means of heating buildings owing to its mild and genial temperature, the freedom from leakage, danger of explosions, &c.; and it may be remarked that this particular branch of engineering—that is the heating of public buildings—does not receive the amount of engineering attention it ought to do. Speaking with all respect of the skill and ability of architects, it cannot be expected that they should know this branch of the engineering profession any more than they understand the making of boilers and engines, and it should be left in the hands of men who make this a speciality. It very frequently happens that at the end of a job where the building and its appointments are all that could be

desired, the heating is not satisfactory, and the fault is due to the necessary amount of attention not being given to the subject at the outset. The most commonly accepted system to-day in the heating of public institutions, such as hospitals, workhouses, asylums, &c., where the buildings are constructed on what is termed the "block" or "pavilion" system, instead of having a fuel-heated boiler at every section, the heating installation consists of powerful steam boilers, which distribute their steam to steam heaters, or calorifiers, fixed in each section and attached to their requisite amount of piping. Such calorifiers do the work most satisfactorily and save the trouble of a large number of fires, fuel storages, &c. A test has been made of a small installation consisting of 164 square feet of pipe and radiator surface exposed for the purpose of warming business premises, the heating medium being a calorifier fitted with one square foot of indented tube surface and supplied with steam, as per following table. For illustration of the apparatus see Plate 6, where A shows calorifier, which is fitted with an automatic steam control arrangement B, heating pipes and radiators CC and DD.

Referring to automatic attachment for controlling the steam supply, this is operated by the expansion and contraction of the body of the calorifier A, and can be adjusted to maintain any desired temperature in the pipes and radiators.

When it is desired to heat water in bulk for bath and similar purposes, the calorifier is attached to a storage vessel, as shown in Fig. 2, Plate 6.

Following upon the heating of water in circulation for warming buildings, it will be interesting to refer to the heating of water in bulk by live steam; and in so doing the writer would refer to a test that is given in the standard work by Mr. Thomas Box, viz., "A Practical Treatise on Heat," page 176, where the result of an experiment is given in an apparatus illustrated at Fig. 3,

Calorifier Test.

(See Plate 6.)

Test made 25th September, 1896, at Manchester. Temperature of atmosphere 55° Fah.	
Amount of heating surface in Calorifier. A....	1 square foot.
Amount of radiating surface in pipes, &c. C.C.D.D.	165 square feet.
Quantity of water in pipes, Calorifier, &c. C.C.D.D.	567lbs
Temperature of water in pipes at start	60° Fah.
Steam pressure, registered on gauge fixed in cover of Calorifier, at start.....	50lbs.
Time taken to heat Installation to a temperature of 180° Fah., as registered by thermometer on flow pipe	60 minutes.
Remarks.—10 minutes after reaching the above temperature on flow, and at a temperature of 140° Fah. on the return pipe, the automatic steam control attachment B came into action and reduced the steam pressure to 34lbs.	
Total amount of steam condensed to water at 212° Fah. in 70 minutes = ...	128lbs.
Total amount of steam condensed during the following two hours in maintaining the temperature of 180° Fah. in the pipes, &c.	124lbs., or 62lbs. per hour.
Condensation per minute in heating up	1·83lbs.
Condensation per minute in maintaining temp...	1·03lbs.

Remarks.—The boiler supplying steam to the Calorifier was a small vertical boiler 5ft. 6in. × 2ft. 9in. diameter with two cross tubes, and was worked at a pressure of 90lbs.

Steam from the above was supplied through a Reducing Valve to Calorifier at a pressure of 50lbs.

Plate 6, which consists of a coil 138 feet long × 1·34 inches diameter, having a surface of 48 square feet, and supplied with steam at 274° Fah. = 31lbs. pressure. The vessel surrounding the coil contained 880lbs. of water at a temperature of 46° Fah., having a proportion of one square foot of surface to 18·3lbs. of

water, which water was heated to 212° Fah. in four minutes, and in eleven minutes more 550lbs. of water were evaporated. The object in calling attention to this is to show that in the experiment Mr. Box did not obtain the proper results from his test, for the simple reason that he had a coil which was too prolonged, a considerable portion of the latter end of the coil being simply a drain pipe for the condensation that had already taken place; and it is necessary to point out that it is a common practice to-day for people to refer to such a text book as this and set out their heating plant on its basis.

By comparison with a plain tube test illustrated in Fig. 1, Plate 4, but with steam at 274° Fah. (31lbs.), one square foot of plain surface heated 23·3lbs. of water in four minutes, as compared with 18·3lbs. heated by the coil, and an equal amount of indented tube surface heated 44lbs. of water in the four minutes, thus showing by comparison even with the plain tube that 27·3 per cent. increase of efficiency is obtainable when the whole of the surface exposed is operative; and by way of continuation of this criticism it will be interesting to point out that in spiral coils fitted flat in such vessels as vacuum pans, in sugar refineries, or other vessels for heating up sweet liquors in the same process of manufacturing, that long continued coils have the same difficulty, that they are too prolonged to be operative throughout (Fig. 1, Plate 7). An ingenious device introduced by Mr. Chapman, of Liverpool, is a wedge-shaped box with a central division, from one side of which the coil starts with its steam supply, and into the other side of which the coil terminates with its condensation (Fig. 2, Plate 7). This gives every coil its own steam and drain, and no doubt the results obtained are a great improvement on the old system, but here will be seen the liability to short circuit in the smaller coils. The device is patented by Mr. Chapman. Another device resorted to for the purpose of getting better results is

illustrated in Fig. 3 of Plate 7, where each tube is of equal length and gets its own supply of steam and runs perfectly straight to the drain box, the results obtained being about equal to two to one obtainable with plain tube surface. It might be stated that in dealing with liquors of a greater density than water it is necessary to increase the heating surface. For instance, in heating sweet liquors the surface needs to be doubled as compared with heating water of the same volume.

It has been the practice in heating water for use in public buildings to use steam of a low pressure, probably through fear of putting too great a tax on the strength of the apparatus employed. This is a false policy, as will be seen by the following table. The heating efficiency of steam goes up in proportion to its pressure, and high pressure steam means much more compact apparatus.

Table shewing the Efficiency of Heating Surface at various Steam Pressures.

Steam Pressure in lbs. per sq. in.	5	10	15	20	25	30	40
Quantity of Water raised from 50° Fah. to 180° Fah. in gallons per square foot of Heating Surface per hour	35	42	56	62	80	93	103

Much more might be written, and many devices introduced, which go to show that the tendency of engineers interested in the questions briefly referred to in the paper has been for them to devise tortuous passages for the fluids to pass through, so as to obtain the greatest efficiency over a given surface. Many of these are ingenious, many complicated, and many having difficulties in point of weakness owing to their construction and the methods of jointing resorted to. Whatever the theory may be as to why a given surface of one form should be more efficient than another, it is very evident that in dealing with

fluid or condensible gases such a rubbing or frictional action is very valuable in preventing any collection of air globules or films of liquid due to condensation on the surfaces, thus maintaining a higher efficiency throughout the operation.

In conclusion, the writer would like to give the invitation to any members who chose to witness a series of tests bearing upon the questions raised in the paper. It is hoped that the patience of the meeting has not been unduly drawn upon by dealing with what might be termed the trivialities in the great subject of engineering, and that some little light has been thrown upon the subject dealt with.

DISCUSSION.

Mr. W. H. Fowler said that up to a few years ago the question of heat transmission through plates was regarded simply as one of mensuration, involving only the application of a two-foot rule and the calculation of the area, quite regardless of conditions under which the heating surface operated. Investigations made during recent years, however, had considerably modified impressions formerly held, and shown that the question of heat transmission through plates raised many intricate problems.

With regard to the effect of scale on boiler plates, and the reference made to it in the paper, he had frequently observed statements in text books that the presence of $\frac{1}{16}$in. of scale caused a loss of 15 % of efficiency, $\frac{1}{8}$in. a loss of 30 %, and $\frac{1}{4}$in. as much as 50 %. He thought however that these statements, without qualification, were apt to mislead. To those who had practical experience in the working of steam boilers these statements were not borne out in practice, and in the course of their duties they often found boilers working under conditions which, if Mr. Graham's figures quoted in the paper as to the effect of

scale were true, ought to be almost incapable of generating steam, and yet such boilers were found doing a fair degree of duty with comparatively little loss of efficiency. In his opinion, generalisation, as to the effect of scale in interfering with heat transmission through plates had been of too sweeping a character, and based on insufficient data. There could be no doubt that scale did interfere with the *rate of flow* of heat through a plate, but in considering questions of this kind the *time element* must not be overlooked.

Further, it should be remembered that the chemical composition and physical properties of scale varied within wide limits; they might have it almost as hard as stone and closely adhering to the plates, or very loose and porous, and the conductivity of such scale varied almost as much as its chemical composition. In some boilers in which there was hardly a trace of scale to be found, showed on the other hand serious evidence of overheating, this being due simply to the presence of a fine powdery deposit in the water, accompanied very often with grease. In other cases they would see scale half an inch to one inch in thickness, and yet the boiler apparently working on without suffering injury, or loss of efficiency.

In the transmission of heat through plates it was necessary to have a certain head or difference of temperature before they could get the heat to flow into the plate on the fire-side, and also a certain difference before the heat would flow out on the water side. Experience showed that the temperature head required to get the heat into the plate from the hot gases was greater than that required to get the heat out of the plate into the water. If the escape of heat into the water was interfered with obviously the head or difference was increased, but this head tended on the other hand to increase the rate of flow through the coating of scale, and provided the heat was not forced through the plate at too rapid a rate no difficulty was

experienced, even with a thick coating of scale. It might be that in a boiler the plates over the furnace were not passing as much heat as they otherwise would do if they were clean and free from scale, but it should be remembered that if the heat did not get through at this part the gases passed at a higher temperature to some other part of the boiler which under normal circumstances did less duty, the result being that more work was done there. In a word, if the heat did not get through at one place it got through at another. If a coating of scale made the furnace plates less efficient, some other parts of the boiler were rendered more efficient. The figures as to the effects of scale were based upon experiments made with a limited heating surface, whereas in steam boilers the heating surface is very extended, and the work done per unit of area varied within wide limits. A square foot over the fire, under normal circumstances, did probably more than ten times as much as a square foot near the chimney.

As bearing on the point he quoted the results of tests made in America some time ago. A small jacket containing water surrounded a vertical pipe $\frac{3}{4}$in. in diameter, which served as a chimney to a Bunsen burner; after a certain lapse of time the increase of temperature of water in the jacket was measured, the tube was then coated on the water side with $\frac{3}{32}$in. of plaster of Paris and after the same interval of time it was found that the same temperature was attained by the water, showing that the coating had no appreciable effect on the rate of transmission. Had, however, the rate of flow of heat been forced beyond a certain pace, say by using a more powerful burner, no doubt a difference in the results would have been noticed. This test was only a laboratory one, and personally he did not attach any great weight to it, but still he thought it was of some interest as bearing on the point at issue especially as regards rate of flow of heat. He thought it was the neglect of the

element of time in the transmission of heat which had led to some misunderstanding as to the influence of scale.

He hoped it would not be inferred from the remarks he had made that he defended the presence of scale in boilers. It was no doubt desirable to keep boilers as clean as possible on general grounds, and although the presence of a certain amount of scale might not interfere with the efficiency of the boiler so long as it were lightly worked, still it would be a different matter if it came to be hard pressed. The presence of scale might then be a source of serious trouble. To his mind grease was far more dangerous in a boiler than scale. This was shown in some tests made by Mr Durston, and given in a paper read before the Institute of Naval Architects. He showed that a thickness of $\frac{1}{16}$th of an inch of greasy matter on the water side of a plate caused, in one experiment he made, an increase of 200° or 300° Fah. in the temperature of plate, and brought it close on to the border line of overheating.

Turning to the efficiency of heating surfaces, and the particular performances of the indented tube which had been brought under their notice in Mr. Row's paper, it certainly was remarkable that the indentations of the tube should have such an extraordinary effect on its efficiency. That it had this effect was undoubted, for he had proved it personally, and there was no doubt that with steam passing through the interior of the tube and water surrounding it, or *vice versâ*, the tube was capable either of heating water or condensing steam at about twice the rate of a plain tube of equal area. This was due he thought to the scouring action of the steam on the surface of the tube, which largely increased the efficiency of the surface.

That great increase in the efficiency of heating surface could be effected was strikingly shown, he thought, by the difference of behaviour in locomotive boilers when working on the rails and when working stationary. When running on the rails it

was no uncommon thing for locomotives to work continuously, and supply 15,000 to 18,000lbs. of steam per hour at 160lbs. pressure, evaporating over 9lbs. of water per lb. of coal, and working with a draught of 6ins. to 8ins. of water. When the same locomotive, however, is put to stationary work on a fixed foundation, it is found difficult to get more than 4,000lbs. of steam out of it, and if any attempt is made to increase the draught beyond $\frac{5}{8}$ or $\frac{3}{4}$ of an inch of water trouble is experienced from leaky tubes. This difference in the rate of working was, no doubt, due to the fact that when running on the rails the mechanical vibration set up, facilitated the delivery of steam from the heating surfaces, and this permitted of them being worked at a much more rapid rate.

That the facility for the removal of steam bubbles played an important part in the efficiency of these tubes was, he thought, shown in the table of results given in the paper, comparing the plain and indented tubes when in horizontal and vertical positions. On looking at the results given it would be seen that for the plain tube the horizontal position gave the best results, which was what he would naturally expect, as in the vertical position the bubbles of steam or currents of hot water would cling more or less to the surface of the tube in rising, and thus prevent the upper part from being as efficient as it otherwise would be.

With the indented tube, on the other hand, the vertical position proved to be the most efficient, though the difference in results between the horizontal and vertical position was not as striking as it was in the case of the plain tube. The superiority of the indented tube over the plain one for condensing or heating purposes was undoubtedly remarkable and deserving of serious attention at the hands of all engineers interested in steam-power installations.

Referring to evaporative condensers, he was glad that the author had touched on this in the paper. It was a matter of surprise to him that in a community like Manchester, which was practically the headquarters of steam and boiler engineers in this country, the evaporative condenser was not more frequently employed. If its advantages could only be brought home to steam users in crowded cities, where water and floor space were expensive items, he was sure we should see more of them at work. It was difficult to get the idea out of the minds of steam users that if they used a condenser they must necessarily require more water. Of course it could be easily shown this was often not the case, and he should like to emphasise and bring home to steam users the fact, which Mr. Row had pointed out, that when there was a non-condensing engine it was possible, by using an evaporative condenser, not only to increase the power of that engine and diminish the coal bill, but also at the same time lessen the amount of water used; and, as the paper pointed out, by adopting the admirable design shown, it was possible to put down an apparatus sufficient for a 200 HP installation on a space little bigger than a card table.

The question of heating feed water with live steam had always been to him a somewhat puzzling one. Great economy he knew was claimed for it by some engineers, and he could easily understand why the introduction of hot feed water instead of cold, even if live steam was used to heat it, was desirable.

It prevented much of the racking stresses set up in steam boilers by differences of temperature, and which led very often to heavy bills for repairs, and tended to materially shorten the life of a boiler. But while admitting all this, and favouring the heating of feed water with live steam, he failed to see where the economy, treating the question as a thermodynamical one, came from, and should be glad if during the course of the discussion some light were thrown on this point.

Mr. SAMUEL BOSWELL said with regard to plates it was a question of their readiness to absorb heat on the one side and give it off on the other, and the thickness had little to do with it, and this fact must be considered in discussing the question of scale. He was rather surprised that Mr. Row should have gone back 39 years in order to obtain facts as to transmission of heat through scale. It was peculiar they should always select sulphate of lime, a harmless scale which gave no trouble. If sulphate of lime was such a dreadful non-conductor, why not use it for covering steam pipes and other heated surfaces? It was certainly much cheaper and easier applied than many of the non-conducting compositions now offered. To illustrate these remarks on loss of heat through scale, Mr. Boswell here showed several specimens of scale taken from boilers, including sulphate of lime, which had made no difference in the boiler efficiency, and others, some of which did and some which did not affect the transmission of heat, grease or floury stuff, he said, the most dangerous thing in boilers. People who talked about scale and its effect on heat transmission ought to always qualify their statements, and he might say that if they never got anything worse than sulphate of lime they would be very lucky.

No one with a knowledge of boiler engineering generally would doubt the efficiency of the indented tube. Its efficiency was due to the fact that it was continually breaking up the streams of heated gases, steam, or water, whichever were passing through it. It brought it into direct contact with the surface at so many points, whereas in the plain tube there was all along the surface a sort of neutral zone, preventing anything from coming into direct contact with it. There could not be the slightest doubt that where applicable at all the indented tube was the most efficient, providing the surfaces were kept clean and free from grease. The straight, easy-flowing brook never

washes its banks while the winding stream scours them away. If they got grease or carbonate of lime or magnesia present they would not work more than a week without trouble.

Mr. E. G. CONSTANTINE was surprised that Mr. Row had gone back so far as '58 for his data as to scale. With regard to the statement so frequently put forward by disincrustant composition vendors that $\frac{1}{16}$in. scale produced a loss in efficiency of 15 %, he had traced its source, and found that it was simply an estimate by Professor J. G. Rogers, of a United States College, and was not an ascertained fact, as was so often stated, but simply an estimate. In preparing a paper for the Association some years ago, the only results of experiments he was able to obtain which were at all reliable as to the effect of scale on evaporation were some carried out by the Society for the Inspection of Steam Boilers in Munich, reported in *Mechanical World* for November 30th, 1883. The tests were made with purified water and a clean boiler, and with ordinary feed water saturated with gypsum. Although the thickness of scale on the heating surfaces was found to be $\frac{1}{4}$in. to $\frac{3}{8}$in. thick, it had no effect upon the evaporative efficiency of the boiler, although a point was reached at which, from what he could gather, further accumulation of scale might have been dangerous, if the experiments had been prolonged.

Dealing with the effect of grease in boilers, Mr. Constantine gave some particulars of the tests carried out by Mr. Durston, Chief Engineer to the Navy, in 1893. The figures and particulars of experiments he had given, he continued, did not at all coincide with the report Mr. Row had read from Berlin, and before accepting that report he should want to know what were the conditions under which the tests were carried out? As to the use of heated air for combustion, he did not consider the result obtained of 11·2lbs. of water per lb. of combustible from

and at 212° was so very remarkable, and he thought it would not be difficult to show examples of Lancashire boilers working in this country, and obtaining equal results in ordinary practice, without the use of heated air.

The table on Page 62 on steam condensation in exposed pipes was extremely valuable, and one which engineers had been in want of for a very long time. There were tables given in various hand-books, but these were generally unreliable, and when he came to investigate their source he found, in some instances, that one or two tests had been made and the rest of the results had been calculated.

As to live steam heating, no doubt it appeared, theoretically, a little paradoxical that heat could be taken from live steam to heat water, and economy of fuel be obtained from it; but, whatever the explanation might be, it really was not a case of robbing Peter to pay Paul. The advantage to be derived from live steam feed heating was so well established in marine practice that it was utterly futile to kick against it. It was undoubtedly a fact, established over long sea voyages, that in average practice an advantage exceeding 10 % absolute economy of fuel had been obtained by the introduction of live steam feed heaters. Certainly there were many cases in which it might be adopted when the ordinary fuel economiser was not applicable.

As to actual results obtained by using indented tubes, he might mention that two years ago, on his advice, some of the indented tube calorifiers were adopted at the Manchester Workhouse, which was built on the pavilion system, and the result was that although with the plain tube they had been unable to get sufficient hot water for requirements, there was now quite as much as was wanted, and obtained from a much smaller apparatus. He had also put in these calorifiers at other establishments with very satisfactory results, and had put down one or two feed heaters on the indented tube system, for heating

feed water for boilers. He had been astonished with the results. He, however, was strongly of opinion, and always insisted upon it in any heaters he had to do with, that steam and not the water should pass through the tube, because although the contraction and expansion of the tube would throw off any scale that might accumulate on the outside, he should be afraid of diminished efficiency with a sedimentary water passing through the tube. The paper contained a great deal of very useful information, and was one of the class that was required, as it contained really practical data, obtained by actual experiments carefully carried out. He was strongly of opinion that there was a great future for the indented tube, as by its design the fluid passing through it was broken up, and all the particles brought into intimate contact with the surfaces of the tube in a manner which was impossible with a plain tube.

Mr. W. INGHAM had hoped that the author would have referred to the question of the relative value of thick and thin plates in transmitting heat, on which there was much difference of opinion. Mr. Blechynden—who had he regretted to say just passed away—had made some experiments which showed that the external thermal resistance of metal plates was so much greater than the internal, that the latter could be ignored in comparison and had no appreciable effect upon the rate of conduction. The difference between plates $\frac{1}{8}$in. thick and $\frac{3}{8}$in. did not exceed 1%. As to scale, the greatest amount occurred not over the furnace plates but at the parts where the circulation was most sluggish. The scale over the furnace was usually very thin, and this was probably the reason why in practice the scaling of a boiler did not affect the economy or efficiency very much.

One reason why we could use thicker plates now without the same tendency to overheating was that we had homogeneous

steel, whereas in the wrought-iron plates there was a greater tendency to lamination. There was a lack of really reliable information on the question of the thickness of plates and their relative powers of transmitting heat.

As to heating buildings, he was doubtful whether steam or water would be the medium for this purpose in the immediate future. Heating and ventilating by moist fresh air frequently renewed, was a much more rational and healthy arrangement, and was now being largely adopted by our leading architects. He agreed with Mr. Fowler's remarks as to the great value of the evaporative condenser, and wondered it had not come more into use where water and land were scarce. Mr. Row's paper would, he thought, give an impetus to this most valuable method of condensing. It would, he hoped, in time do away with the enormous and costly mill-lodges, which were often dirty, foul, and sources of disease.

Mr. W. Bayliss thought the separator shown on Fig. 1, for separating moisture from steam was almost obsolete. In a separator of this kind although the diaphragm arrested the moisture in suspension from the incoming steam, this moisture whilst attempting to drop into the receiver below was swept off from the bottom edge of the diaphragm by the steam in its passage to the exit branch. A much more efficient form was that where the steam entered a receiver of comparatively large area in a downward direction either at the side or the top, and the exit branch was placed at the top or near the top of the receiver.

By this arrangement the moisture suspended in the incoming steam was carried to the bottom of the trap due to its momentum, whereas the steam being of less density than the water it was easily deflected to the outlet branch.

Mr. T. SETTLE said there was no doubt about the value of the indented tube, but would like to know whether the author had tried any experiments as to its ability to resist pressure, internal and external. As to heating buildings, the system adopted at several buildings he had inspected, and which was found to give most satisfactory results, was to heat the air by passing it over a large number of tubes in chambers which were filled with hot water and kept at a moderate temperature, the air before passing over the tubes being moistened, and afterwards forced into the different parts of the building.

Mr. H. RENOLD said he had had one building heated with high-pressure steam, and the other with hot air, the floor spaces of the rooms being 20,000 feet in the one building, and 12,000 feet in the other. These two systems having been working side by side, he had ample opportunity of testing one against the other. The result was that the system where warm air was forced into the rooms by a big fan was incomparably the superior system. The general comfort, absence of headache, and increased vitality of the workers, had determined him to take the high pressure steam system out and replace it by the forced hot air system.

It was certainly astonishing that evaporative condensers were not more generally adopted. He was going to put a plant down of two to three hundred HP for producing electric light and power, and should certainly not have a big water tank, but an evaporative condenser where a current of cold air and trickling water is used. He would condense his steam and use it in the boiler again and again.

The PRESIDENT (Mr. J. Nasmith) said he was strongly of opinion that the best way to heat a building was to heat the air at one point and then drive it into the building. They could

not trust to natural ventilation; the air must be driven in. The propulsion system was the only one which has proved absolutely successful. The new Technical Schools at Manchester would, when completed, possess one of the most complete systems of that sort in the country. There would not be a single fireplace in the whole building. The air would be drawn from the top of the building, washed, filtered, and heated, and delivered by ducts throughout the whole building and into every room. In a system of that sort an efficient heating surface became a necessity, and the problem was to get the best possible result with the least possible heating surface.

With regard to the 11·2lbs. of water obtained with the boilers in Dublin, they must remember that this was got by using an inferior coal to what had been previously used.

Superheated steam had advantages of its own, but they were rather to be obtained in the engine than in the boiler.

With regard to evaporative condensers, he agreed that their use should be very much greater. They must not however, forget that in England, largely owing to climatic conditions, they were very rarely short of water. Consequently, a certain type of condenser having been taken up, and water being easily and cheaply found for it, there was apparently no necessity to charge, as the question of cost did not arise. In some tests made some years ago respecting an evaporative condenser, the fact was brought out that although the condenser proved to be of some value, and really did give tolerably good results, there was the practical disadvantage of having to put it on the top of the building in order to get a free current of air about it. In the paper, however, the description of the effects of using an induced draught through an evaporative condenser of the type described showed them that the condenser could be placed in any convenient position, and thus do away with the objection referred to above. The results given as to the enormous advan-

tages of this reduced current of air carried the subject a long way forward. Personally, he thought we were now on the eve of a practical carrying out of the principles of evaporative condensing which had not been accomplished up to the present.

He had pleasure in moving a hearty vote of thanks to Mr. Row for his interesting and valuable paper.

The motion was seconded by Mr. Fowler, put to the meeting, and carried with acclamation.

Mr. Row in responding, said with regard to the fact of his having gone back to '58 for information on the scale question, he did it for the reason that even the most modern books contained the same information, and if untrue was seriously misleading to young engineers depending upon such works of reference.

As to the effect of grease on heated surfaces it was undoubtedly detrimental, and he found in actual practice on marine heaters that a great amount of this, with sludgy matter, was arrested in the heater on its way from the pump to the boiler. The heater itself performed two important duties, viz., the heating and the partial cleansing of the feed water. The heaters were arranged with special facilities for cleaning.

He had carried out considerable experiments in the heating and cooling of oil, and it was necessary for the heating and cooling of a given quantity of oil to provide twice as much surface as was necessary in the heating or cooling of the same amount of water.

Another experiment which might prove of interest to some, was trying to boil milk by steam. The experiment consisted of suspending a piece of steam heated tube, and placing around it a vessel containing milk, drawing it away almost immediately; but the few moments in which the milk remained in contact

with the tube was sufficient for the latter to get hold of the grease and glutinous matter contained in the milk, to a very considerable extent; and afterwards putting the milk around the tube it took a very long time to get to boiling point.

With regard to thickness of tubes, when they started making heaters for marine purposes they used the same thickness of tubes as for land requirements. The Board of Trade said they were not thick enough, and consequently the thickness was almost doubled, but a test showed that there was very little difference in efficiency between 16's gauge and 10's gauge.

As to the separator illustrated, it caused the steam to pass on practically in dry quantity, and it did not appear that there was any necessity for prolonged and tortuous passages; such long passages rather tending to put friction on the steam, and consequently reduce its value.

As regards the efficiency of heating surface, the table given showed the efficiency at varying steam pressures, not a given body of steam, which meant a great deal of difference. He did not mean to say that 1lb. of steam at a higher pressure would do so many different duties as given, but that the same apparatus supplied with steam at higher pressure would do so much more work. There was a corresponding increase of condensation.

The indented tube proved itself equally as strong as the round tube. The Board of Trade had tested the tubes prior to sanctioning their use in marine apparatus. When the ends of an indented tube made from 1½in. solid drawn copper, 16's wire gauge, were secured between tube-plates, the bursting point was 2,720lbs. per square inch in one instance. The average pressure may be taken as 2,000lbs.

With respect to heating buildings, he strongly objected to the system of heating at the bottom of the building and then conveying the air, which they all knew readily parted with its heat, through long, cold conduits, and finally discharging it

into the room. He agreed with the chairman that forced ventilation was a great necessity to bring the fresh air up to a room, and that it should be heated before being delivered into the room, but they must let the heat be there, and not convey the heated air all over the building.

Before adopting the last named alternative they must consider what course was best, to have the heated air in, or close to the room, or down in the cellar, near the sewers and all the heavy foul atmospheres of the place. The screening of ventilation had been very successfully accomplished in Scotland by means of a sieve with trickling water, which when starting to run down was perfectly clear, but before reaching the gutter at the bottom was in a black, inky condition. This proved a valuable arrester of solid matter.

Heating feed water for steam boilers by live steam was undoubtedly a great advantage; it improved the circulation in the boilers, and saved quite 10 % of fuel.

With regard to scale on steam heated surfaces, it appeared that to heat up to boiling point scale was a great detriment, but according to argument at that meeting certain scales, such as sulphate of lime, were no serious detriment on fire heated surfaces in steam production, but carbonate of lime was to be very carefully avoided on furnace surfaces. The first difficulty was to raise the water to boiling point, which was best done in a feed heater before the water entered the boiler.

He thanked them most cordially for their vote of thanks.

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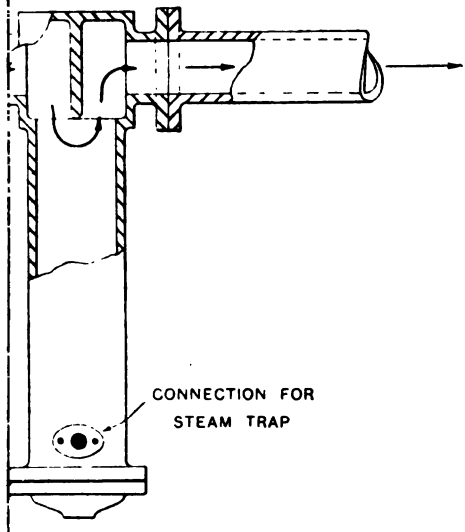
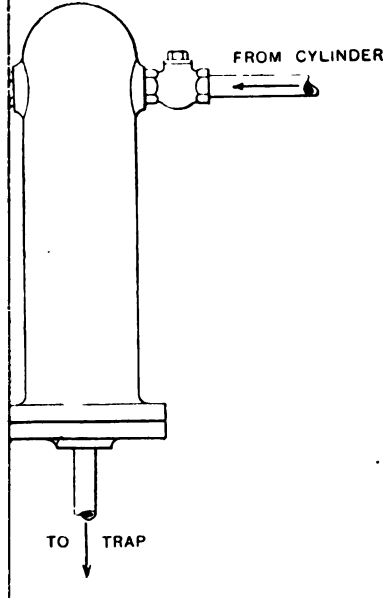
10 Plates follow illustrating this Paper.

HEAT THROUGH SURFACES.





EAM PIPES AND CYLINDERS

UNIV. OF MICH.

MOTOR VEHICLES FOR ROADS.

READ SATURDAY, 27TH MARCH, 1897,

BY

Mr. W. WORBY BEAUMONT, M.Inst.C.E.,

LONDON.

The most difficult of the problems in the design, construction, and working of mechanically propelled vehicles for common roads, are only less formidable as they present themselves to-day, than they were to the men of from sixty to seventy years ago. Some of these problems were very perseveringly attacked, and as far back as sixty-five years ago so much success was attained with steam propelled vehicles, that some knowledge of what was made and tried seems a proper preliminary to any new approach to the subject. The rivalry of the leading inventors and workers in this field seventy years ago was very strong, and the bid for public favour and support was well backed by very meritorious mechanical achievements. Although much has been published recently describing in general terms the character of the steam vehicles which attracted so much notice between 1824 and 1833, some attention may be usefully given to points on which little has been said.

We may glance at the results of the work of Gurney, Hancock, Dance, Summers, Ogle, Church, and others, with a view to extracting therefrom some useful hints after the lapse of sixty-five years.

1. See Cantor Lectures, *Society of Arts Journal*, 2nd, 9th, and 16th December, 1895, by the Author; also Paper of the 27th November, 1896 (*Society of Arts Journal*); and Lectures to Liverpool Chamber of Commerce, 9th September, 1896, and Self-propelled Traffic Association, 19th January, 1897.

Walter Hancock made a number of coaches, including the "Autopsy," the "Enterprise," the "Era," and others, all of which were fitted with powerful engines and a remarkably high type of boiler, working at a very high pressure, and containing points of great interest to us at this day. It is moreover quite probable that his method of constructing wood wheels will yet be found worthy of imitation. The "Automaton" for instance, Fig. 1, was constructed to carry ten or eleven passengers and conductor and driver on seats in the front part of the vehicle in *char-a-banc* fashion; the rear part of the vehicle carried the engine and boiler, and contained between them a place for some inside seats. The engine was vertical, placed nearly midway in the length of the vehicle, and it had two cylinders of 9in. diameter and 12in. stroke, and with a crank shaft which was geared to the driving axle by means of a stout common chain, running on grooved and pocketed chain wheels 10in. in diameter. The coach in working order weighed about 8½ tons and the driving-wheels were 4ft. diameter. Running at ten miles an hour the engines would thus make only about seventy revolutions a minute, and hence the necessity for the large dimensions of the engines as compared with the dimensions which would be adopted to-day if gearing of any kind, or a chain such as Hancock used, were employed.

The boiler which Hancock invented and with which he was very successful, Figs. 2, provided steam for his engines ordinarily at a pressure of from 60lb. to 100lb. on the square inch, with an ordinary safety valve load of 70lb., but he had used pressures as high as 400lb. The boiler consisted of ten chambers, each about 30in. by about 20in. and 2in. in thickness, made of charcoal plate ⅛in. thick. The sides of these chambers were embossed all over, so that when the chambers were assembled the bosses met and acted in the place of stays to prevent the

distortion of the chambers under pressure, and at the same time leaving ample space for the passage of the products of combustion between them. The heating surface in one of these boilers was about 100sq. ft. and the grate surface 6sq. ft. That is about 8sq. ft. of heating surface, and 0·8sq. ft. of grate surface per horse power, taking an average pressure of 85lbs. per square inch in the cylinder. The chambers were riveted together at the vertical edges and the top, each chamber being formed of a single plate bent up in the middle, the bend forming the bottom edge without a seam. Towards the top and bottom of each chamber, holes about 8in. in diameter were made in the chamber sides, and gun-metal rings acting as distance pieces were placed within the chambers at the bottom, and narrower rings within and between the chambers at the top. Through all these rings and through strong side plates, and small end chambers carrying the safety-valves and for the attachment of fittings, were passed strong bolts, by which the whole structure was firmly held together, the collars forming chambers, the lower one for the receipt of the feed-water, and the upper one acting as a steam chamber; the boiler so constituted was kept from half to two-thirds full of water, and only on one occasion did the boiler ever show any weakness, and even then, although one of the plates split, nothing more happened than the mere stoppage of the engines. Besides the two bolts mentioned for holding the boiler together, two others passing through the ends of strong bars at the centre of the end plates were used. One of the coaches in which this boiler was employed used to run an eight-mile stage and from 7cwt. to 8cwt. of water, or, say, 115lb. per mile, were used; at the same time about two bushels, or 80lb. of coke, were used, hence making an allowance for the full fire at starting the boiler evaporated at least 10lb. of water per pound of coke burned, say, a total of 11½lb. per mile. I think, therefore, I am justified in again

referring to Hancock's boiler as one which is not without suggestive value.*

Gurney's coaches and tractors have been referred to on many occasions, but I would draw particular attention to Gurney's boiler, and to some figures concerning it, to which attention has not been drawn. The coach, Fig. 3, unlike Hancock's, was driven by a pair of horizontal engines, and the road wheels were 5ft. in diameter; the driving axle was the crank shaft of the engines. The crank shafts in the different coaches were the cause of considerable trouble, trouble which was avoided by Hancock by using a straight axle and a driving chain. So many of Gurney's coaches were made and used by himself, Sir Charles Dance and others on different roads, that a short description of the arrangement of the machinery may be given.

The engines were of what was then known as 12 nominal steam horse-power, with cylinders 9in. diameter, 18in. stroke, and about $\frac{3}{4}$in. in thickness; they were at first made of gun-metal, but cast iron was found to be best; cut-off took place at about half stroke; being direct coupled the engines were, of course, slow speed engines; forced blast was used as it was by Hancock, Hill, and others, but Gurney's fan was on a vertical spindle driven by the little vertical crank shaft of a little engine on the fore carriage, which also worked two feed pumps; the exhaust steam from the engines passed into and from a tray-formed tank under the coach by means of which the water was heated on its way to the boiler, the feed-pipe being taken into the uptake space and heated on its way to the delivery into one of the steam receivers of the boiler. The exhaust steam finally passed into the uptake and escaped highly superheated into the atmosphere through one of four chimneys. The boiler shown in Fig. 3 is of the kind which Gurney made when he

* For further particulars as to Hancock's boiler, wheels, and coaches see the author's "Cantor Lectures," *Society of Arts Journal*, 1896.

fitted them with vertical separators, two of which were used as steam chests in which the water from the steam was deposited and found its way back to the lower water trunk of the boiler; steam was taken from the top of these receivers by a pipe which passed along under the coach body to a point below the driver's seat whereat was situated a regulating cock and lever. Subsequently Gurney gave up the use of these vertical receivers and used an upper horizontal receiver as seen in Fig. 4.* This boiler was successful, but I have not been able to find the amount of heating surface it contained; at first a great deal of trouble was experienced by the splitting of the tubes, but afterwards tubes with lap welds were obtained and little further trouble was met with. The boilers were tested to 800lb., and worked at from 70lb. to 120lb. With 70lb. Gurney estimated that he got 20lb. per square inch in the cylinders, presumably meaning an average pressure with cut-off at half-stroke. Various sizes of tubes were tried, and tubes 1in. internal diameter were preferred. With a coach weighing about 3¼ tons ready for the road, about 10 gallons of water were used per mile and about 20lb. of coke, a consumption which, though only approximate, seems very high, for it gives an evaporation of only about 5lb. per lb. of fuel; and the water consumption, as far as can be gathered from Gurney's statements before the Select Committee in 1831, would seem to have reached as much as from five to seven gallons per HP hour, or from 50 to 70lb. This is assuming the HP to be twenty, but if we take only the average pressure of 20lb. in the cylinders, and the speed of slightly over eleven miles per hour, giving sixty revolutions of the crank per minute, the estimated indicated HP would be only fourteen. Gurney's estimate of 20lb. is, however, probably far below the mark, for even assuming that the 70lb. steam fell 20lb. on the square inch on its way to the steam chest,

* Cantor Lectures.

the average pressure throughout the stroke was probably much nearer 40lb. than 20lb. In any case, however, it would appear that Gurney's tubular boiler was not as efficient as Hancock's thin, flat chamber boiler, and this is borne out by the fact that Sir Charles Dance, who had several of Gurney's coaches, found it desirable to improve the boiler, and he invented and patented certain modifications which he embodied in the boiler known under his name, Fig. 5. Gurney had about five years experience of the running of his coaches and tractor vehicles, and he concluded by experience that a piston-speed of 220ft. per minute was as high as it was desirable to use, and this affords a further check on what was the maximum horse power of his engines. With regard to the weight of his coaches and tractors, he used to reckon each 10 cwt. of vehicle and its machinery as equivalent to one horse of the four horses usually used on an eighteen-passenger coach. It is noteworthy that in his experience, as well as in that of Hancock, one driving wheel was found sufficient for all ordinary running. One of Gurney's tractor vehicles was sent down to Cyfarthfa, where Mr. W. Crawshay fitted it with cast iron flanged wheels early in 1830, and ran it on a piece of railroad three miles in length, when it hauled sixteen and a-half times its own weight. Dance's boiler, Fig. 5, was an interesting form of tubular boiler in which the fire was completely surrounded except at part of the ends by tubes which formed grate bars, water-heating tubes, and steam tubes, but we do not find much evidence as to the performance of this boiler, for it was only finished a few months or a year before the coaches ceased running.

Another boiler of considerable interest is that of Maceroni and Squire, which was a tubular boiler, a modification of Sumner and Ogle's combined water and smoke-tube boiler. These are shown by Figs. 6 and 7. Maceroni and Squire ran their coach about 1,700 miles almost without repair, and the cost of coke

was only from 3d. to 4d. per mile, which, as was the case with Gurney and Hancock, was only a fraction of the cost of the food of the four horses otherwise used, including the spare horses which were necessary. The engine used was a double-cylinder horizontal, mounted on the perch pole, and with cylinders 7½in. diameter and 15¾in. stroke. Fig. 8 shows Maceroni and Squire's coach. Sumner and Ogle's coach weighed three tons in running order. The boiler shown by Fig. 7 had 250 sq. ft. of heating surface, and about 6ft. of grate surface; it weighed about 8cwt., and consisted of vertical water-tubes, through which the smoke-tubes passed, these tubes being fitted and fixed in horizontal top and bottom cross-tubes of rectangular external section and circular internal section, apparently made of cast-iron.

The boiler was 3ft. 8in. in height by 3ft. by 2ft. 4in., and was worked at a pressure of 250lb. It supplied a double-cylinder engine, the cylinders being 7½in. diameter and 18in. stroke, coupled direct to a crank driving axle, the driving wheels being 5ft. in diameter. The engine was stated before the Select Committee to be of 20 HP., and this, with the statement as to fuel and water used, gives an evaporation of 7lb. of water per lb. of coke, and about 56lb. of steam per HP per hour, running the coach at an average speed of ten miles, with from a ton to a ton and a-half of passengers.

Hill's coach, Fig. 9, differed considerably in general design from those previously mentioned, the under-frame being more like that adopted in railway work, including the springs and horn-plates used for the main bearings of the crank-shaft, which was worked by a double-cylinder vertical engine; both wheels were drivers, and the crank-shaft was apparently in two parts, connected by what is now known as a compensating motion, this being the first instance of its use. The boiler as seen was a vertical boiler which was adopted by Hill after previous

experience with his partner, Burstall, who in 1824 designed and patented an arrangement of steam coach in which an instantaneous steam generation boiler was employed, and in which all four of the wheels were driven.

An arrangement of coach with two double cylinder engines actuating independent crank-shafts, one to each driver, and a well thought out arrangement of spring suspension was patented by W. H. James, Fig. 10, in 1824, this being the first suggestion of the use of independent engines for each driving wheel, making compensating gear unnecessary.

I will only only refer to one more illustration of the ingenuity and practical character of the designs of many of the inventors of sixty years ago, namely, the water and smoke tube boilers of Church, Figs. 11 and 12. One of these, Fig. 11, is, it will be seen, a combination of vertical boiler with smoke tubes and horizontal shell boiler with completely water-cased fire-box, and with a water bridge or a row of vertical stop-ended tubes forming a bridge. The air for combustion was supplied by a fan below the large grate. Fig. 12 shows the arrangement of the same boiler converted into a water-tube boiler. Dr. Church's coach, or one of his designs, is shown by Fig. 13. These are only a few examples of the designs of coaches, boilers, and motors made, and many of them used at a time when the country was not ready for them, and it will have been seen that in many points the boilers and other details were forerunners, very closely followed by things of very recent date. Reference may be made to the high steam pressures used by some of these men, and it is much to be regretted that the courage and ability with which these high pressures were provided for and used, was discredited by the adverse opinions of some of those who were supposed to be more scientifically informed than those who used them.

From the time that it became obvious that the vested interests in all that related to ordinary horse haulage and the powerful competition of the railways, working under statutory powers, made steam road vehicles impossible in this country, little was done for many years until the traction engine period.

The interregnum was relieved from complete stagnation by road steamers, such as those made by Ricketts, of Stafford, Fig. 14, for the Earl of Caithness and for the Marquis of Stafford, road steamers which weighed about 30cwt., and only carried three or four persons in very considerable discomfort, and a stoker. The steamer made for the Marquis of Stafford in 1858 had a locomotive form of boiler supplying steam to a horizontal engine, on one end of the crank-shaft of which was a pitch chain pinion, by means of which, at a ratio of 1 to 2½ the 8ft. driving wheels were driven. The road steamer made by Ricketts for the Earl of Caithness was very similar to that of the Marquis of Stafford, but the engine drove the main axle by gearing instead of by chain, and it weighed 50cwt. A road steamer was made in 1861 by Messrs. Carrett & Marshall, and like those of Rickett ran on three wheels; it carried seven or eight passengers and a stoker, but as it weighed over six tons it is not of very great interest now, although it, known as the "Fly-by-night," acquired a very high degree of notoriety.

In 1845 R. W. Thompson invented and patented (No. 10,990) the pneumatic tire for wheels, and he called them his aerial wheels. His pneumatic tire consisted of an outer cover which he made of leather, and of an inner tube which he made of india-rubber and canvas. His outer cover was held on by bolts passing through the leather and the felloes and tires of the wheels, but of course he was not confined to that method of holding, and I believe he attached the leather cover by other modes than those shown in his patent specification. Thompson experimented with these tires, but being born long before the

days of cycles his experiments were made with tires of very large size, and on very heavy wheels. A trial on a brougham showed that they might be run 1,200 miles without much or very serious wear. Experiments were also made to ascertain the difference of the draught of a vehicle with aerial wheels and those with ordinary tires. The result was a saving of over 60 per cent., it was stated, on ordinary roads, and a gain of 300 per cent. on newly-metalled roads. Experience, however, did not encourage Thompson, and many years later he departed from his promising aerial tire, and was the cause of the infusion of new life into road steamer construction through the introduction, in 1871, of solid indiarubber tires. The road steamers were, however, of the heavy kind, that is to say they were vehicles carrying a heavy vertical shell boiler of the Field type, with small heating surface, and, therefore, small horse-power per unit of weight. One of these road steamers is shown by Fig. 15. Others were made with the horizontal or ordinary locomotive type of boiler, but the cost of the tires, which were put loose upon the wheels, was so great, and the wear and tear even when shod with a form of linked iron tire, that the system was ultimately abandoned. A set of three tires for the Ravée cost £241, the tires being 5in. in thickness and 10in. in width. Mr. R. E. Crompton attached these encircling linked tires in various ways, including wire rings very like those now used to hold rubber cycle tyres. Somewhat similar tires are, however, now used, but the interior part is made of harder rubber, and this vulcanised on to the rim of the wheel. In this way Messrs. Burrell have overcome the difficulty which attended the rolling out and breakage of these massive solid rubber rings. About the same time, and a little later, numerous forms of spring wheels, with steel and with rubber springs and buffers, were invented and tried, but none of them have withstood the test of prolonged experience.

Numerous road steamers about this time, and down to 1876, were made by Mr. A. F. Yarrow, the well-known torpedo-boat builder; Mr. H. P. Holt, Messrs. Tangye Bros., Mr. A. Paterson, Mr. H. A. Mackenzie, Loftus Perkins, J. G. Inshaw, J. W. Bolton, Leonard Todd, and others, for particulars of which I must refer to my "Cantor Lectures" already mentioned, and the Paper I read before the Society of Arts last November. In all these, with the exception of Perkins, who used a Perkins' tubular boiler and a pressure of 450lb., the boiler was of the heavy, large water space kind. One of the most original of these was that of Mr. Holt, made in 1866-7, in which the two driving wheels were independently driven by two little double-cylinder engines, the crank shafts of which were connected by pitch chain to the driving wheels, the engines running independently, as was partly suggested forty-two years previously by James. Mr. Holt used a higher type of boiler than the other designers I have mentioned. It was a fire-engine boiler with Field tubes, and there were several points of mechanical interest in his carriage; the exhaust from the engines passed into a cast-iron box, which formed a baffle plate at the bottom of the uptake. From this, highly superheated, it issued almost noiselessly and generally invisibly from five jets. A similar device for this purpose was used by Mr. Mackenzie in his steam brougham. The Perkins road steamer was a one-wheel steam horse or tractor, the one wheel being fitted with a Thompson rubber tire and steel chain link tire outside it. The boiler was carried immediately over the driving wheel, which was 25in. in diameter, and 12in. wide, and it only occupied a space of 26in. in height, 15⅝in. wide, and 20⅜in. long; on one side of the boiler was carried a water tank, and on the other a little high speed engine connected by bevelled gearing to the road wheel. The average steam pressure used in the engine was 250lb. during experiments which Perkins made, with a light

van which, with load, weighed 57cwt. The steam from the engine, which was compound, with two pairs of cylinders, was passed by a pipe to a condenser with a water tank under the vehicle it hauled. The speed was only three miles an hour. The weight of the steam horse was 32cwt., so that it only hauled about double its own weight, but if arranged to receive more of the weight of the vehicle hauled, and if carried on two wheels instead of one, this proportion might be considerably improved.

During the period which I have just been dealing with, the traction engine and the self-moving and agricultural engine and road locomotive made great strides in the hands of Messrs. Garrett, Aveling, Burrell and Sons, Fowlers, G. & H. McLaren, Ransomes, and others, and there can be no doubt that with the traction engine and road locomotive builders rests a good deal of the future of the steam road vehicle for the heavier work. They have, during many years, acquired immensely valuable stores of practical information concerning the design, form and behaviour of materials as used in road engines for all kinds of heavy work, and, however much we may in future change the character and reduce the weight of the boilers used, and, however much we may increase pressures and engine speeds and decrease engine dimensions, this information, with ability to apply it, will be required. Whatever the other changes made in future may be, the actual net power required to move a ton of vehicle and load will remain the same. There is no doubt, however, that the difference between the work done by the engine and that given off at the periphery of the road wheels will be tremendously lessened, in other words, the efficiency of the transmission between crank shaft and road wheel will have to be enormously increased. The masses of heavy cogwheels and heavy shafts and large bearings, the one high qualification of which is that they cannot be broken, will have to give place

to gearing of much higher efficiency. In some cases chain gear will be in many respects preferable to any other, and in a few cases engines directly coupled to the main shaft will be used. On the other hand, for that road traffic which requires the employment of trains of loaded vehicles, only comparatively small modifications or departures from existing road locomotive practice, or from the double chain traction engine made by Burrells nearly thirty years ago, will be required. Considering the requirements of high-class traffic on the roads in days to come, and the facilities which the Light Railways' Act should afford for that class of heavy traffic which requires trains to carry it, it is questionable whether it will be policy to allow the ordinary roads to be permanently used for it. It is unnecessary here to describe the main features of these traction engines or their bearing on future motor vehicles, but the value of the experience acquired by their use must not on the one hand be neglected, and on the other must not be allowed to misguide us with regard to what is really necessary as to weight and strength for things which are not heavy traction engines, with heavy boilers and heavy gear, and the roughest of usage.

Turning now from this digression to the new-born interest of the past three years in motor vehicles, an interest which has been the means of freeing British engineers from legal restrictions which made any development impossible in this country, we come to the era of the light high-speed motors, and of vehicles propelled by a motor which is one of very recent times *i.e.*, the oil and mineral spirit motor.

Each year since and including 1894 our French neighbours have organised races of mechanical road vehicles propelled by steam, mineral spirit, and elecricity, and encouragement was given to makers by the proprietors of the *Petit Journal*, who offered prizes of considerable value for the best and fastest motor vehicles of numerous kinds, including motor cycles.

Races were run in 1894, 1895 and 1896, the race of September last being from Paris to Marseilles and back, a total distance of 1,070 miles. The main features of this race and the extremely adverse conditions under which a greater part of it was run are generally very well known, and the fact that thirteen vehicles accomplished this race of 1,070 miles, the best of them at an average speed for the whole distance of 16 miles per hour, shows that, notwithstanding the slight repairs which were necessary in some cases, these vehicles have reached a considerable state of efficiency. In this race none of the steam carriages were amongst those which were successful, although in 1894 and 1895 the De Dion and Bouton, and the Serpollet carriages were amongst the winners. Serpollet did not compete in 1896.

Again, in a race last January between Marseilles and Monte Carlo, a distance of 144 miles, the race was won by two of De Dion and Bouton's tractor vehicles, hauling landaus or waggonettes. The road is very hilly, but an average speed of 18·7 miles an hour was maintained during the whole run, which was performed in three sections. There were thirty-seven starters, including nine motor-cycles. Most of the motor-carriages were constructed by MM. Panhard and Levassor, and by MM. Peugeot Freres, and were propelled by mineral spirit motors. Only half the starters went through the race, the circumstances of which were not favourable to the comparatively small power of the petroleum spirit motors, although several of these were fitted with more powerful motors, namely, 6 to 7 HP., than the makers usually employ. The steam-tractors were heavy vehicles, and succeeded because they did not meet with any of the mishaps which had troubled them in 1895 and 1896. Their victory, however, does not necessarily point to the general applicability of the system for carriages for which minimum weight with maximum seating capacity is the most essential quality. The winning of the race

was, moreover, only a question of a quarter of an hour and upwards, as against several of the lighter and far more convenient spirit motor-carriages.

It may, therefore, be fairly concluded that for those users who would be satisfied with a lower power than that necessary to maintain a speed of 18·7 miles an hour on a hilly road, smaller motors might very well be employed, especially if a slow or reasonable hill speed was deemed sufficient. It cannot be too often repeated that well-constructed motor-carriages can be driven on good ordinary roads with very small power, and in a general way it is not until the carriages have to be lifted up hill that the demand for considerable power arises. A little consideration will show how much greater this power is than is usually supposed, and how much more advisable it is for many reasons that a moderate hill climbing speed should be adopted.

A few figures, by way of example, may be given. Taking a vehicle which when fully loaded weighs say 2½ tons the power required on a good level road would be about 2·5 HP for a speed of eight miles an hour, or of about 3·75 HP for a speed of twelve miles an hour. To mount a hill some parts of which may be on a gradient of 1 in 20, the 2·5 HP rises to 10·5 HP, but if a speed of three miles per hour were deemed sufficient for climbing the gradient of 1 in 20, only about 4 HP would be required. Now, for dealing with bad roads these quantities ought to be doubled, so that to take 2½ tons of vehicle and load up a gradient of 1 in 20, at the rate of eight miles, would require about 20 HP, whereas if a reasonable speed for the hill climbing were adopted only about 8 HP would be wanted. This, of course, means that some form of speed reducing gear for hills must be employed, but this may be of a simple kind, and it would secure lessened first cost of motor, lessened cost of working, smaller weight, better arrangement, and more room for the machinery, and if a steam motor be employed a lessened

weight of boiler and of condenser, and practical possibility of producing a vehicle of moderate weight instead of the prohibitive weight which high speed hill climbing means.

Among the vehicles which first attracted attention in Paris were the steam vehicles of Le Blant, Serpollet, Scotte, Bollée, and De Dion and Bouton. The Serpollet and the Dion and Bouton with, on one occasion, the Scotte, have been most prominently before the public during the recent racing periods. The carriage of M. Serpollet, Fig. 16, is distinguished from all others by the form of instantaneous generator boiler which is known by his name. There is nothing new in the instantaneous generation of steam, but M. Serpollet, as is now very generally known, adopted a peculiar form of tube and numerous devices connected with it, so that the manipulation by the driver of the vehicle becomes very simple. As at first made the tubes were flat and with only a capillary passage in them, but at the present time the tube instead of being flat is crescent form in section, and the passage is from $\frac{1}{16}$in. to $\frac{3}{16}$in. in thickness or width and about 2in. in length. There is no water space in the boiler, and steam is only generated when the engine is running and driving a pump which sends water into the heated tubes stroke for stroke of the engine. Formerly the tubes, which were placed within a casing over a coke fire of considerable size, were cast into a cast-iron covering, but now the tubes are made of thicker section and the cast-iron covering dispensed with. A hand-pump is employed for injecting by two or three strokes enough water into the boiler tubes for starting the engine, and a by-pass is provided by means of which some of the water pumped by the engine returns from the bottom row or rows of tubes to the feed tank, when the engine has only light work to perform. An advantage of the system is that the user has no concern respecting the water level in the boiler, and experience seems to show that with clean water no trouble arises from incrustation

in these very narrow tubes, and this is the experience not only of French users, but of Mr. J. Brown, of Belfast, who has been running one for a considerable time. The occasional high temperature of the tubes with no water or steam in them, and the scouring rush of the steam when formed by the introduction of the small spurts of water, appear to keep these tiny passages open. In a more recent carriage, Figs. 17, M. Serpollet modified his generator to some extent, and experimentally used a petroleum burner, Fig. 18, known as the Longuemar burner. In it ordinary lamp oil is supplied under pressure at *A* to the coil *B*, and after circulating through it passes away as oil gas at *C*, down the pipe *D* into the central chamber of the burner, which is closed by means of a valve on the end of a rod *E*, actuated by some form of lever *F*. From the central chamber the gas can, when the valve *E* is opened, pass to the burners *G G G*. It also passes to two burners at the ends of arms at right angles to the arms carrying the burners *G*, and shown by dotted lines, but as it enters these from the lower chamber below the valve, these burners are not extinguished when the three first mentioned are; thus when it becomes necessary to stop the engine $\frac{3}{5}$ of the power of this powerful burner is shut off and $\frac{2}{5}$ remain to keep the boiler warm and to act as pilot lights for the other burners when full steam is again required, and the lever *F* moves the valve *E*. The position of this burner under the carriage is shown in Fig. 17. In the first mentioned Serpollet carriage* shown in section, a coke fire is used, fed automatically by the descent of the coke which is in the bunker between the boiler *G* and the water tank *E*, and it will be observed that with large or small fire the tubes were subject to its heat almost as much when the carriage was standing as when it was running. The petroleum burner might thus be a great improvement. In the carriage, Fig. 16, it will be seen that a small double-cylinder

* *Engineering* 18th and 25th October, 1895.

horizontal engine was used, the pistons of which were 2½in. diameter with 2½in. stroke, and which were connected to two cranks in the usual way on a crank-shaft, which by means of one pinion actuates a second motion shaft by a spur wheel on a hollow shaft, one end of which carries the outer ring of a neat form of spur wheel compensating motion. On the ends of this second motion shaft are pinions having ten teeth gearing into pitch chains, by which the road wheels are driven. In the newer vehicles (three-wheeled) the engines have inclined cylinders and give motion to the driving wheels by means of spur gearing of about 5 to 1, the pinions on the ends of the crank-shafts gearing direct with wheels on the drivers. In both carriages the steam passes into the space above the top tubes of the boiler, and from it into a downward chimney or escape pipe in a superheated condition, so that it is generally imperceptible. I have said so much concerning the Serpollet system, because whether precisely in accordance with the designs of M. Serpollet or not, there appears to be good reason for belief that the instantaneous steam generator, or an analogous generator, may for road and tramway vehicles be an important element in the future success of steam carriages. Of the engine used by M. Serpollet, it is not necessary to say more. M. Serpollet is now making a new form of oil burner.

The Count de Dion and M. Bouton have been very energetic and persevering in their attempts to make a successful steam carriage. At present they have achieved most success with the steam tractor already mentioned in connection with the Monte Carlo and Marseilles race. The boiler used in these tractors is of the water chamber and tubular class, Fig. 19, with what might be called a central fuel column, and is a remarkable steam maker. This boiler, in a modified form, has been employed for fixed engine purposes. It consists of a circular water casing, made up of the outer shell and cylindrical fire-box ; in the centre

of the fire-box space, about a foot from the bars, and extending about 9in. above the top of the boiler shell, is a central chamber or pot, the upper part of which forms a steam dome. This central chamber and the outer water shell are connected by short, straight, radial, upwardly-inclined tubes in considerable number, the upper rows being superheating tubes. Very good results are obtained by the boiler, Fig. 19, but of course its water-level has to be watched as with an ordinary boiler, and when the carriage is stopped the production of steam for a considerable time continues, and much care would have to be exercised in this country to prevent the noisy escape of steam. It is, however, a type of boiler which is of considerable interest, although in all probability the future will lie with more completely tubulous or water-tube boilers. The Dion engine is horizontal, and, with the second motion shaft driven by it, is carried in one frame, the engine being compound with overhanging crank pins a main pinion in the centre of the shaft driving the exterior of the differential motion. The slide valves are worked by eccentrics on a separate shaft driven by pinions, one on each side of the main pinion.

Exceptional lightness for most vehicles will be aimed at, and the steam engine will have to compete with the oil motor, for in spite of its undisputed advantages, the steam-engine and boiler together are of more weight, and in some cases more trouble than its mineral spirit competitor. The very small coil boiler made some years ago by Mr. Blackburn, patented by him in 1877, is said to have had great evaporative power; it was heated by a Bunsen methylated spirit burner, and was, it seems, merely a close coil of tubes about $\frac{1}{2}$in. diameter or less. It provided steam for a small Brotherhood engine fitted to a three-wheeled dogcart, the subject of his patent, but it does not appear that anything like a severe test to prove its capacity for ordinary road travelling was ever made.

In this country of recent date, the Steam Van and Waggon Company have made steam vans, Fig. 20, in which a Thorneycroft water-tube boiler has been employed with a small vertical compound engine. This van and its parts I have fully described before, and it is only necessary to say that for a van capable of carrying a maximum load of one ton on good roads, and weighing itself, ready for the road, 30cwt., the boiler and its casings weigh, I believe, about 9cwt., and contains 50 square feet of heating surface and 2½ square feet of grate.

Now, the weight of this boiler is at least as much as the weight would be of an oil motor of equal engine power, and this leads me to consider the relative merits of the steam and oil or spirit motors, though either may be the better in different cases.

With the steam-engine we have greater range and ease of manipulation, within the limits of no power and full power, than with any other motor; for short periods it may be made to give more than its proper maximum, it may be stopped and started with more freedom, certainty, and smoothness than any other motor, with the exception of the electrical; it may be employed for travelling any distances with fuel available everywhere, is easily fitted with reversing gear, and is easily understood.

Now, for long distance work the only competitor at present with this is the oil or the spirit motor, the disadvantages of which are small range of power within the maximum, no excess of power for short periods, difficulty of starting, and consequent necessity for keeping the engine running when the carriage is stopped for short periods; vibration due to explosive impulse on the piston, and necessity for running the motor at nearly full speed before starting the vehicle, most of the change of speed having to be made by frictional or other gearing. The motor and vehicle cannot be started together, and hence whenever the vehicle is started the motor is called upon to attempt to impart to it a speed equal to that proper to the lowest ratio of the speed

gear. A frictional gear means loss of power and loss of time in overcoming the inertia of the vehicle, and unless the frictional clutch is connected to the motor through very low speed positive gear, the starting is almost certain to be effected more or less jerkily. To avoid the difficulties attending the use of all variable speed gears in which the gear not in use is running whether at work or not, the author devised the "antinertia" power gear and clutch, by means of which any driven thing may be put into motion by positive gear at a low speed, and in which the gear for the time being doing the work, is the only part in motion.

Having described the disadvantages of the oil or spirit motor, it is necessary to describe their merits as compared with the steam-engine. The first is that the oil-engine requires no steam generator and no condenser. It uses fuel of a high calorific value, easily carried, and no trouble to apply, and it uses it more economically than the same fuel, oil, can be used for the generation of steam. As it needs no apparatus for the generation of the working fluid, there is no such apparatus to attend to, and no space required by it. Hence the motor and gear can be much more conveniently arranged than the steam-engine. This it is that gives it all its advantages over the steam-engine, even assuming all the little troubles connected with boilers and condensers to be entirely overcome. The motor will, however, weigh a little more than the steam-motor of equal power, running at equal speed, and this may, perhaps, be put at 25 per cent. The weight, moreover, of a boiler and condenser is not all in excess of the oil motor, for jacket water arrangements and exhaust silencer have to be included. The oil motor cannot, however, use the cheapest fuel, such as coal or coke, or even crude or the partly refined petroleums, and this is an objection to it for the larger powers and for vans and vehicles, which must in any case have a paid driver and attendant to whom the work of stoking would be part of his duty. It is, moreover, an

objection to oil engines for such purposes that they in some respects depend upon more delicate adjustment as to air, vapour, and oil supply, admission and ignition, and it is not always that even those well acquainted with oil-engines can say precisely and at once why an oil motor will not start, or being started will not continue to work. The cause may be one of a dozen things which are not obvious, and which may take a good many minutes to find out. In a corresponding sense the steam-engine is not at all delicate, and this is an advantage it will probably offer for a considerable time, but with decreasing oil force as motors become more definite or fixed in points which are now subject to adjustment, and are more generally understood. In the oil-motor, either the main or the supplementary air supplies may be too much or too little, the oil supply may be too much or too little or may stop, the exhaust or the air valve may either of them leak or be made temporarily to leak, by dirt under the seat or part of it, or by corrosion or erosion, and in any of these cases it is difficult to say what is happening. The ignition tube may not be hot enough; this may be seen. It may be stopped or partly so, which cannot be seen, and this must be guessed, or like any of the other numerous things must be diagnosed. To sum the matter up, it may be said that the steam-engine would be in every way the best were it not for its boiler and condenser or escaping steam; and that the oil-motor is best where the boiler and condenser are both inadmissible, and where the vibration it causes and its occasional freaks (which are diminishing in frequency) are not sufficient reasons for rejecting the advantages of motor carriages.

We are thus led to the conclusion that steam propulsion is mainly a question of steam generator, for, although a condenser is very desirable, the passage of the exhaust steam into the uptake, as was done by Gurney, Hancock, Holt, and Mackenzie, might be considered sufficient means of disposal for many kinds

of vehicles. A condenser is not, however, an impossibility, and a combination of the air and evaporative condenser systems will probably lead to the solution of the problem. Such generators as that used by H. S. Maxim for his flying machine suggest another line of development. This boiler* contained a very large number of thin $\frac{3}{8}$ copper tubes, connected to larger trunk tubes, none of them containing much water and a steam receiver of small diameter. Most of the tubes were only $\frac{1}{50}$in. thick, and with four of these in a white-hot furnace Maxim found he could evaporate 26½lb. of water per hour per square foot of surface. His boiler was heated by gasified naphtha, and contained 800ft. of heating surface, and weighed 1,000lb. with feed heater. Inventions and patents for light steam generators are numerous enough, but none are yet, or not more than one or two are being used even experimentally.

I have said nothing as to the smell of the oil or spirit motor—firstly, because it is not or need not be really serious, it is only a different stink from that or those to which we are accustomed, either with horses or steam engines, and will be lessened by experience.

With regard to the vibration caused by them, I think there is little doubt that this will soon be overcome. The piston and connecting rod of an oil motor and cylinder are like a shot in a gun, action and reaction being only equalised by different amounts of imparted motion, or of inertia of different masses, overcome at different velocities. A vertical motor operated by explosions at irregular intervals, and mounted on a springy base, is not likely to stand very steady, and, as few motors are properly balanced, the occasional explosion merely aggravates a vibratory movement of smaller range set up by the continuous rotation of unbalanced parts. The difficulty is one which should

* *Journal of the Society of Arts*, 30th November, 1894.

be surmountable, but there is no doubt it is less a difficulty with the horizontal engine, and for obvious reasons.

It is unnecessary that I should again describe either the French spirit motor-carriages of the leading makers, or those of Benz, of Mannheim, or of Lutzmann. They are represented in this country by the Great Horseless Carriage Company, London and Coventry; by the Anglo-French Motor-Carriage Company, Birmingham; by Arnold's Motor-Carriage Company, East Peckham; by Julius Harvey and Company, 11, Queen Victoria-street; by Mr. J. A. Koosens, Southsea, and many of them were illustrated in the Cantor Lectures previously referred to, and in the paper by the author read before the Society of Arts in November last.

I may, however, by means of a few views on the screen, recall some of them to your memory, including those above mentioned and some of those of English make. Here the Author showed by lantern slides a number of the vehicles to which reference has been made. All these Continental vehicles, with the exception of the Serpollet and the Dion, are propelled by mineral spirit motors, several of them by the Daimler motor, which is the only one with which no carburetter is employed. It is a vertical of simple design and works exceedingly well. Ignition is effected by heated ignition tubes. Several of the foreign makers, including the Lutzman, the Benz, the Delahaye, and others, are propelled by horizontal motors, and ignition is effected by electric sparks. No noteworthy improvements have been made in recent months. The gearing used by the best makers, such as M. M. Panhard and Levassor, Fig. 21, remains much the same as when described at the end of 1895. It usually consists of three or four pairs of spur-wheels of different sizes on the engine shaft, driving by one or other of three or four corresponding wheels, a second motion shaft which gives motion to the driving-wheels by chains or by

belts. It has two cylinders, set at an angle of about 15°, and coupled to a crank partly formed by a pair of fly-wheel discs. This motor is entirely enclosed in a box, which also contains the carburetter *b*, and an exhaust box *c*. The reservoir for carrying the benzoline is seen at *d*. At *e* is the regulator for controlling the supply of benzoline to burners for heating the ignition tubes. At *h* is a small centrifugal pump driven by a belt on the pulley *j*, for circulating the water round the cylinder jackets. Gearing is arranged for three different speeds, the cog-wheels *l*, being made of gun-metal, and movable, so that they may either of them be made to engage with the three wheels above them, they are made tight or loose upon the crank shaft by means of friction clutches at *k*. The intermediate shaft driven by this gear conveys motion by another intermediate shaft, placed transversely across the carriage, and carrying a pair of pitch chain pinions which drive the road wheels by a pitch chain on sprocket wheels attached to their spokes. A differential or compensating motion is fitted to the transverse intermediate shaft. To alter the speed while the engine is running, the pedal *m*, is depressed, and the gearing then brought to rest by means of the lever *n*. The change in the position of the gear wheels is then made, the cogs all being rounded at their corners to enable them to find their way into the corresponding teeth of the upper wheels.

A pulley *q*, is placed upon the driving wheels and used for carrying a brake, instead of putting a brake on the tyres of the road wheels.

The clutch already referred to is shown by Fig. 22. The shaft *c*, is the crank-shaft, upon which is fixed the coned disc *b*. In front of this and sliding upon a feather is another friction cone, the face of which has a greater angle. When the containing or interior cone disc which encircles these is pushed against these inner cones, the smaller one retires into the larger

one against the resistance of the springs *d*, and when the frictional contact due to the resistance is reached, the further frictional contact and more powerful grip of the disc b', is obtained, the object being, as far as frictional cone clutches makes it possible, to put the carriage gradually into motion; the faces of the cones *b* and b' are coated with leather at *a* and a'.

Most of the makers who use gear transmission between the engine and second motion shaft employ the three or four speeds, but those who use belts avail themselves of the slip of the belts more or less controlled to vary speed between the two which are mostly used. Belts are not, however, to be commended for vehicles, because the belts must be short, some must be crossed, and all of them may often have to run in bad, wet weather. For light work the shortness of the belts when on pulleys of no great difference in size may not make great tightness necessary, but for variable work the objections to tightness can only be escaped by using jockey pulleys. In some cases where these are used the belt which for the time being is doing no work is nevertheless running idle on one of the pulleys, or loose on both, and this is objectionable. The use of belts as friction brakes, or in place of better variable speed arrangements, is also objectionable, even if for no other reason than that it polishes the pulleys and makes greater tightness, necessary for a given amount of frictional adhesion. We can only say of it that it is not a bad makeshift.

In Great Britain there are now numerous manufacturers who are making or preparing to make oil or spirit motor-vehicles, but for the next two or three months it does not seem that we shall see their vehicles on the road. Some of these makers use the Daimler motor, the construction of the main features of which* is so well known as to need no description here. Mineral spirit is used for its operation.

* See Cantor Lectures.

Two makers are trying what is known as the Pennington motor, which is a small light high-speed mineral-spirit motor, the cylinders of which are made of thin steel tubes, as used by Mr. Hiram S. Maxim in his steam-engines for his aerial machine, and from which Maxim got over 360 HP† from engines which he could support on his lap, weighing 640lb., or less than 1·81b. per horse-power actual. The pressure used was 325lb. Mr. Maxim is now at work, not only on a gas-engine which will run fast or slow like a steam-engine, and reverse, but on a light steam engine and boiler or generator of high capacity, a 12 HP generator being only 9in. thick, and in the shape of a book.

American inventors are at work on the subject, and the Duryea carriage, fitted with the Duryea mineral-spirit motor,‡ is running in this country, and is in the hands of Messrs. Maberley and Thrupp, of Oxford Street, London. Compressed air is much favoured in America, but less progress seems to be made in the United States than in this country.

Messrs. Petter, Hill, and Boll, Yeovil, are also making motor-carriages run with Petter's mineral spirit motors.¶

Messrs. Atkinson, Phillipson, and Toward have made a steam-carriage which has reached the stage of experimenting on the road, and with promising results.

As far as I am aware, the only motor-carriage which is at present being propelled with a motor using ordinary lamp oil, is that made by Messrs. Roots and Venables, of the Westminster Bridge Road, the motor being a horizontal one on the Roots system. I have fully described this motor-carriage recently,** but I may here mention that the motor is constructed on the vaporiser system without any spray-making apparatus,*** and

† *Society of Arts Journal*, 30th November, 1894.

‡ Pat. Specification, 1896.

¶ *Society of Arts Journal*, 27th November, 1896. Paper by the author.

** *Ibid.*

*** See the author's articles on "Oil Engines," in *The Engineer*, June and July, 1894.

is fitted with a governor which controls by acting both on the oil feed and on the exhaust, with the object of avoiding the objectionable smell resulting from imperfect combustion.

Concerning electrically-propelled vehicles, there is still not much that can be said with respect to those intended for more than short runs in towns. The electrical motor possesses all the attributes of a perfect motor for any power within its maximum when used with suitable speed gear to get over the difficulty of starting the vehicle and climbing steep hills. The one practical difficulty is the great weight of the accumulators required for a few HP for a few hours. At present there is no good battery which weighs less than 500lbs. per HP hour, and this weight far exceeds that of the whole motor machinery required for an oil or spirit motor-car.

During this year there are to be numerous public exhibitions and trials of motor-vehicles of various kinds, commencing with the exhibition at the Royal Aquarium in May, and including the trials of the Royal Agricultural Society at Manchester, those which presumably will be made for the competitive prizes offered by the proprietors of the *Engineer* and by the British Motor Syndicate. The conditions of competition for the Royal and for the *Engineer* prizes have been widely published, and the latter include runs of not less than 200 miles, as well as the preliminary trials, but routes and arrangements for the long runs have not yet been made known.

As compared with the men of sixty years ago, we have advantages which in many respects are of the greatest importance, and which ought to enable us to accomplish with ease and certainty that which they left unfinished. In particular we have the advantage of the materials and tools which make it possible to run engines continuously at three times the number of revolutions they could use, and at double the piston speed.

We have, moreover, materials at our disposal which enable us to reduce the weight of our motor machinery by probably 70 % as compared with theirs. We have steel sheet tubes of all sizes and splendid quality, steel castings, drop forgings, and many other such things; we have ball bearings and rubber tires, and we have aluminium alloys, which place in our hands materials for motor parts and frames, water and oil tubes, connecting pieces, and many other things of half the weight of anything then or at present made of either cast-iron, bronze, or gun-metal. Aluminium alloys for castings are now made of specific gravity, very slightly over 3·0, and therefore of considerably less than half that of cast iron, and of much higher strength. Tests made at the Durham College of Science, Newcastle, of aluminium alloy castings from Mill's Atlas Works, Sunderland, of 3·05 specific gravity, have given a tensile strength of as much as 18 tons per square inch, with an elongation of 1·25 %, and another alloy used for castings of bed-plates and standards for engines and dynamos, brackets, gear-wheels, and other parts, has a tensile strength of 15 tons per square inch, and with a specific gravity of only 2·98. The immense advantages such a material offers in the construction of motor-carriages and motor cycles will be readily seen, and should help to remove considerable difficulties.

Compressed air for motor vehicle purposes is again being much spoken of, but I have not thought it necessary to refer to it in previous papers because the economic value of compressed air may be very easily over-estimated. There can be no doubt as to the manipulative excellence and cleanness of compressed air for motor purposes. With a good supply of compressed air, a motor could be worked with all the ease of a steam engine or electric motor for any power within its maximum. It must, however, remain a more expensive power than either steam, oil, or gas, and probably will not under any circumstances cost much

less than from 1·25 to 2d. per horse power hour, and in some cases will cost more when compared by steam to a useful pressure such as 180lbs. per square inch. It will take about twice the volume of steam for the volume of air at the same pressure produced. The receivers for the air for vehicles for even short distances weigh from one-third to one-fourth the whole weight moved, and for distances of say 20 miles the air and receivers would approach in weight half the total moved. With means of heating the air the conditions are improved, but with an increase in the number of parts. Even with this a vehicle which with load weighs 1 ton, would require for 8 mile stages about a half ton of air and receivers, allowing for power necessary for ordinary roads and moderate gradients, and this weight adds to the power required.

Compressed gas commends itself very much more favourably and is not unlikely to be hereafter of great importance in this connection. Four cubic feet of ordinary coal gas at a pressure of say 110lbs. per square inch would represent the heat equivalent of 4 HP hours or about 1 HP hour by a gas engine. This is at least ten times greater than the power a similar quantity of air would give at the same pressure, an excess so great that its superiority is incontestible. The one disadvantage of the gas motor as compared with the air is the difficulty of starting it, and as at present made the necessity for keeping it running light while the vehicle makes short stops. There is, however, little objection to this in the case of tradesmen's vans and many other vehicles, and it does not cause any trouble with the gas driven tramcars as used so successfully and exceedingly economically on the Blackpool, Lytham, and St. Annes tramway, on the Gas Traction Company's system, and as equally successfully at work on the Dessau and the Dresden tramways. The system has the advantage that the motor can get its working fluid in every town and every village of any size, and the motor vehicle

could be provided with a pump by which it could fill its own receivers while the users go to lunch or dinner.‡‡

In the future it is not unlikely that the gas companies will have a small gas compressor as part of the necessary plant and be always ready to supply any gas motor vehicles.

DISCUSSION.

The PRESIDENT (Mr. J. Nasmith) said it appeared to him that, owing to the fact that those who were interested in motor vehicles last year prematurely made a great exhibition of them in that celebrated procession, which took place on the first possible day, the public had, in some measure at any rate, lost some of the interest previously felt. It was another instance of the saying, that it did not do to advertise your goods until you were quite ready to sell them, and so many expectations had been formed as to what the motor cars were going to do, that the fact of their having done so little up to now, although explainable upon a proper basis, had undoubtedly caused some feeling of disappointment in the public mind. It appeared to him that this class of work would develop first in the line of vehicles for carrying comparatively heavy loads. Although Mr. Beaumont rather minimised the unpleasantness of the smell from vehicles driven by oil, there could be no doubt that on a hot, sultry day a good deal of nuisance would be produced if there were thirty or forty oil motor vehicles passing through the street in a town like Manchester. In his opinion steam would be the medium whereby they would get the best results. The advantages of steam were numerous; there was no question that gas engines were by no means so reliable as steam engines; they could not be started or handled so well, nor could the power be put on

‡‡ See *Auto-motor and Horseless Vehicle Journal*, February 17th, 1897, p. 199.

right away, and although friction gear to some extent minimised that difficulty, yet friction gear in itself was always more or less unreliable, and at the best a makeshift arrangement for getting over a great difficulty. What they would have in the future no one could say; the motor industry was as yet in its infancy. Although patents in connection with it had been taken out early on in the century, yet it was, in reality, practically a new thing, and they had much to learn about it, and it would only be by actual experience and trial that the acceptable type of motor would be worked out. Any success attained in anything like the immediate future would be attained mainly by means of steam motors. When they considered the question of locomotion in this country, they found that the goods traffic was infinitely more important than the locomotion of passengers. Passengers as a rule were found in large numbers in cities and towns, where there was the means of carrying them in various ways, very much more conveniently than in country places, but the inter-communication between villages and agricultural districts, and places where the goods grown in the country could be put readily upon railways, involved a question which was a very gigantic one, and which would repay not only the nation as a whole, but the companies individually, for any pains they might bestow upon it, in the construction of motor vehicles which could be readily run, without difficulty, in those parts of the country where locomotion was much more difficult than in the large cities.

Mr. Hans Renold remarked that great efforts had undoubtedly been made, during the past three or four years, to bring a successful auto-car into the market. He had supplied about four or five hundred sets of chains for auto-cars alone.

The question of auto-motors involved numerous difficulties. They all knew how it had taken twenty years of hard work to

bring bicycles into their present state, and these were nothing but miniature auto-cars, with a human being instead of a steam engine, etc., to give the motive power. The question, he repeated, was a most difficult one, and the more he looked into it the more he was convinced that if in 50 years hence they had obtained a decent auto-car they would be doing very well indeed. He was pleased that Mr. Beaumont had referred to the early inventors, and described the boilers, etc., introduced by them, and he (Mr. Renold) wished that they had such men as these in the field now, instead of the company promotors who were now dealing with the matter. With regard to the question of the motor, the President had stated, with the support, apparently, of the author, that there was a great future for steam; no doubt there was, but he had come to the conviction that there would not be one medium, there would be neither steam, gas, nor electricity. These motor cars would be used under very different circumstances. The cars that were running from Manchester to Glasgow, or long distances in the country, required a different power from cars that delivered parcels in big towns like Manchester or London, and they would find that there was a field equally for steam, the gas engine, compressed air, and for electricity. As to the question of transmitting the power from the motor to the carriage or the wagon, he had been struck with the difficulty of getting a wheelwright or a carriage maker to assist an engineer in building a decent vehicle. Although he had tried very hard to see how the chain could be knocked on the head, for transmitting the power to the car-axle, he had not succeeded. They must have a positive action, and also a flexible action, and nothing could give these requisites so well as the chain did, either for auto-cars or bicycles.

Mr. H. WEBB said the question had to be considered under the heads of passenger traffic, vehicles running about cities, and

traction, for agricultural and other produce, on the roads. It seemed strange that inventors had not got out of the old rut, but simply designed the carriages as they had always been. Surely they should be able to produce a better shaped thing than some of those shown on the screen. It was not absolutely necessary to have a large back wheel and small front wheel, or vice-versa; surely some alteration could be effected. If the motor car was to be a success the company promoter should be kept out—he spoiled everything. He did not think either steam or oil would be the motive power, they wanted such skilled direction, whilst there were also the first cost and maintenance, which was quite equal to that of a horse. Electricity was the great motive power of the future, and he thought that some one might be found who would reduce the present excessive weight of the storage battery to moderate limits. The January American Electrical Magazine discussed the relative merits of steam, electricity and gas very tersely and clearly.

Mr. T. Ashbury, in proposing a vote of thanks to the author, said in his opinion they had not yet got the right thing by a long way, and he thought that before the end of the present century they would see a very rapid and great advance in the development of the propulsion of motor cars. They were all very thankful to the lecturer for the time and trouble he had spent in bringing the subject before the Association, and would no doubt be glad to hear from him a further lecture, when greater progress had been made in the development of motor cars.

Mr. Thomas Daniels, in seconding, said he could bear testimony to the car made for the Earl of Caithness being a bad steamer, as he had seen it running. He had not much faith in motor cars, and thought with light railways to carry goods about in country districts, all requirements would be met.

The PRESIDENT, supporting the motion, said the state of the laws had prevented people from making greater progress in connection with motor cars, until quite recently. Now, the attention of engineers would be directed to the question, and we should see, within a very few years, a very great development in the subject.

The resolution was carried with acclamation.

Mr. BEAUMONT, in replying, said it was perfectly true that the Show last November, from the Hotel Metropole in London to the one in Brighton was a little before time in one respect. Nobody here was ready to make any of those vehicles that successfully ran down to Brighton, or to make them with any of the improvements they hoped to introduce into them. Some of the foreign makers were a great deal too busy to trouble about what the English orders might be, and on the other hand English users were not at all in a hurry to buy things which had so many features that were of a foreign character, imperfections they considered, from a mechanical engineering point of view. In many respects they were quite right, but he feared that many people in England would be making a great mistake by starting entirely in a different direction from that followed by those foreign makers, and throwing away the useful experience they certainly had acquired in producing what was a very useful vehicle, where motor vehicles, instead of horses, were preferable for any one of the reasons which would induce people to buy them. The President was quite right in saying that the first development in this country would be in vehicles for business purposes. The little difficulties connected with the starting and working of the motor, and the smell, became of small importance when the vehicles were used for parcels delivering, light goods traffic, etc. As to the length of time required to develop such an apparently simple thing as the

cycle, he must remind Mr. Renold that the simplest thing always came last in cases of mechanical development.

Perhaps in fifty years time the motor car would be a very simple thing, compared with what it was now, but he did not think it would take all that time to produce something approaching a satisfactory one.

As to company promoting, he was sorry to say that in these matters mankind had not changed in the least. Records showed that at the time of Gurney, Hancock, Squire, Hill and others, there was a great struggle to get money from the public, to make more experiments, or put on a number of vehicles, and the promises made were much the same as they were now. The Mechanic's Magazine for 1824-9 would confirm this statement, and would give an idea of how the money-hunters took in hand the inventor, and exploited and worked him just as they did now.

He agreed with Mr. Renold that steam, gas, oil, electricity, etc., all had their field. With regard to electricity, however, although the smoothness of running, ease of starting, stopping, etc., made it a desirable motor for some purposes, it was not suitable at present for runs of any distance. A motor perfectly satisfactory for one place would not do for another; a motor that might work well for Suffolk would not do so well in Kent.

It was amusing to see people trying to do without the chain by introducing something else. They in almost every case tried to do away with a simple and satisfactory means of transmission by the introduction of something a good deal heavier, more complicated, and very much less satisfactory.

Mr. Webb must have a little patience with regard to the design of the vehicles. He was, however, afraid that if makers introduced a car to suit the motor, people would say that they could not use such a thing. Changes would have to come gradually.

In his earliest days he had been with those who were makers of road vehicles, the steam plough, traction engine, etc., and his grandfather, William Worby, made the first road locomotive for farmers' purposes, in order to draw the first steam threshing machine that was ever made. In 1842 the Royal Agricultural Society gave him the Silver Medal for the thresher and locomotive.* The steam threshing machine was then taken back to Ipswich, but no one would buy it, because the farmers did not wish to have a fire engine anywhere near their farms. The engine was taken off and sold as a fixed engine, and the threshing machine was altered and sold as a large four horse machine. Before his grandfather could persuade anyone to allow him to try his steam threshing machine, he had to take out a special insurance on the whole of the farm buildings.

He might mention an incident that happened in 1862 in connection with the "Fly-by-Night" vehicle, which weighed six tons and carried nine people. In this case, after proceeding about thirty miles, they had to telegraph for a new pinion, and afterwards sent a messenger for the patterns, so that they could get a pinion on the road whenever they wanted one again.

* See *The Engineer*, 27th June, 1879.

5 Plates follow illustrating this Paper.

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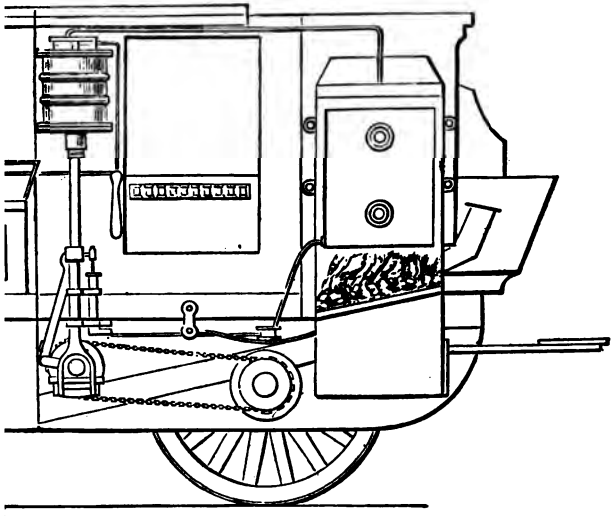
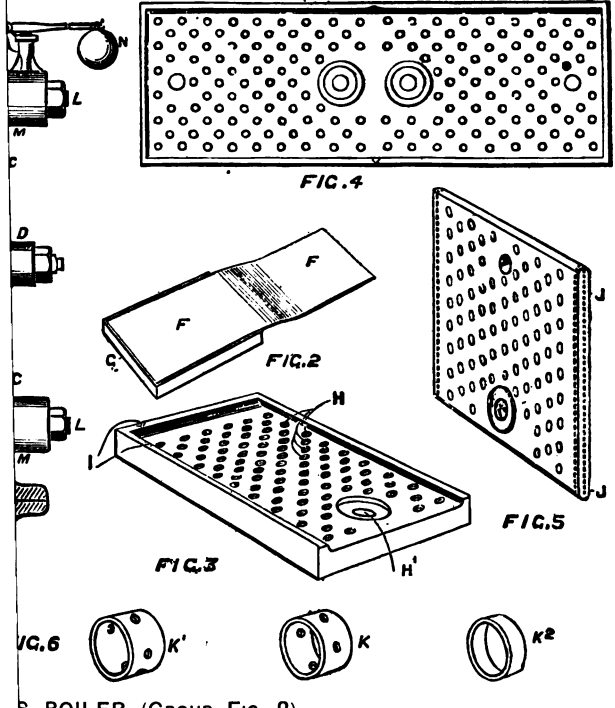
CLES FOR ROADS.



CARRIAGE "AUTOMATON" (1827).



S BOILER (GROUP FIG. 2)

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ICLES FOR ROADS.

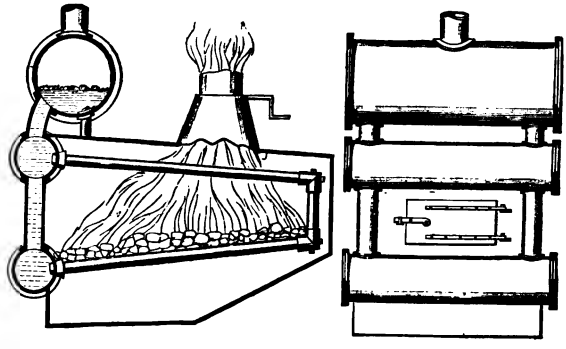


FIG. 4.—GURNEY'S BOILER.

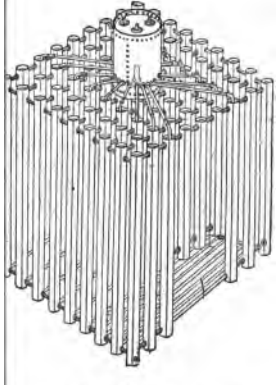


FIG. 7.—MACERONI AND SQUIRE'S BOILER.

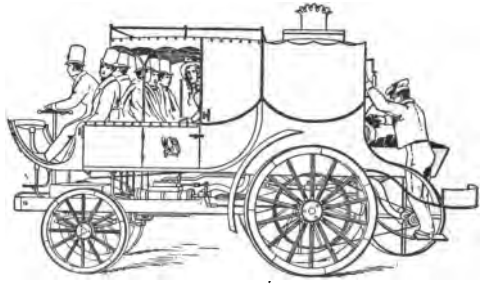
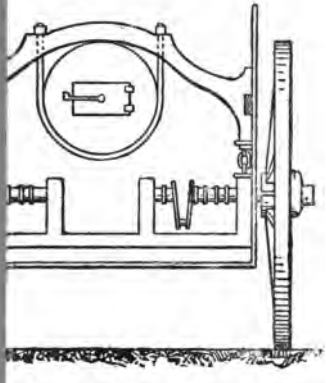


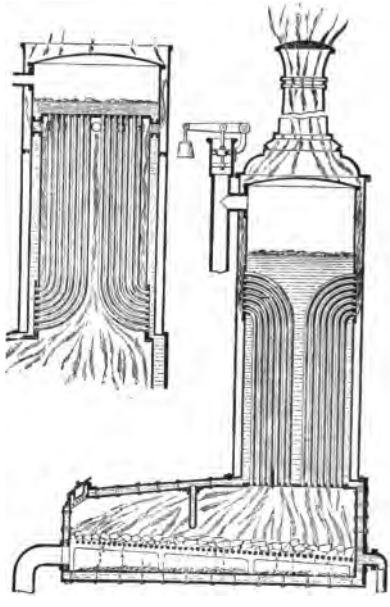
FIG. 8.—MACERONI AND SQUIRE'S COACH.

ICLI

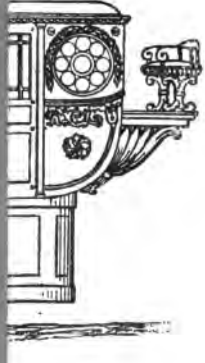
ICLES FOR ROADS.



-JAMES'S CARRIAGE.



FIGS. 11 AND 12.—CHURCH'S BOILERS.



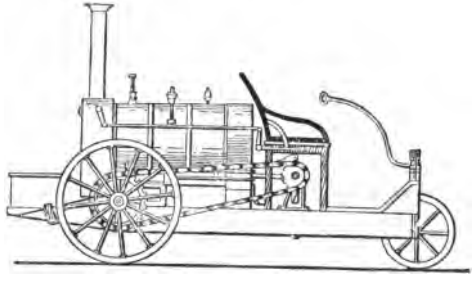


FIG. 14.—THE MARQUIS OF STAFFORD'S STEAM CARRIAGE (1858, RICKETT).

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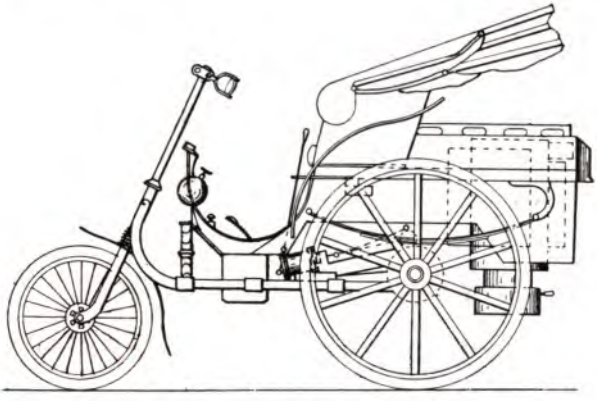

FIG 17.—SERPOLLET STEAM CARRIAGE (LATEST TYPE).

FIG. 17.—SERPOLLET STEAM CARRIAGE (LATEST TYPE.)

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CLES FOR ROADS.

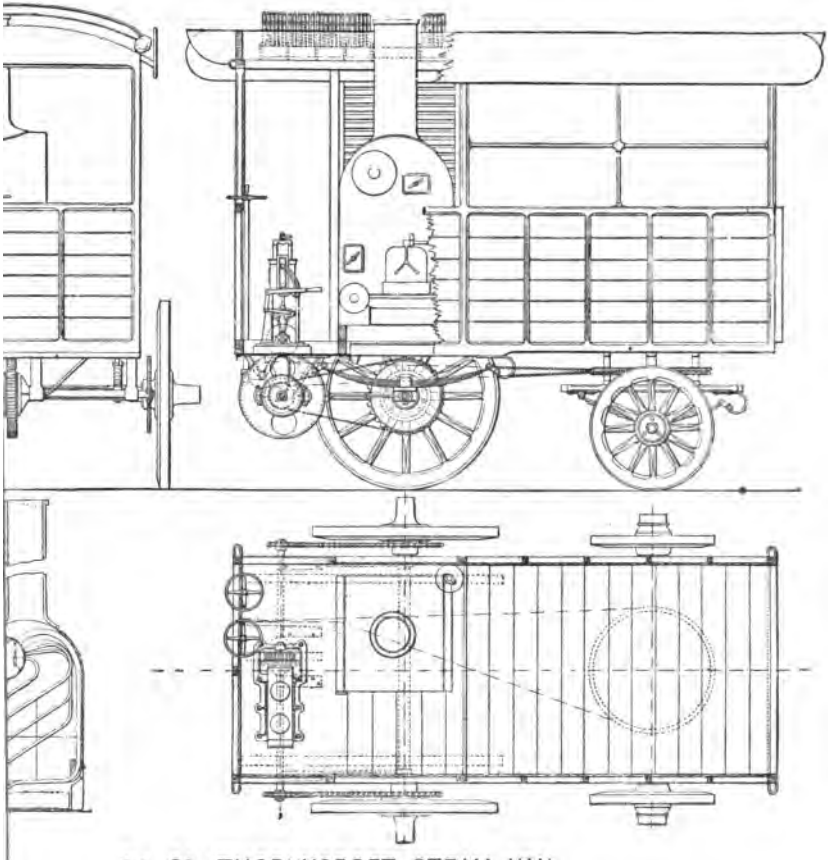
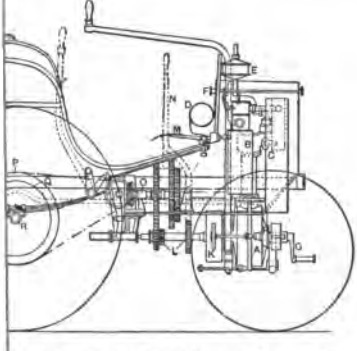


FIG. 20.—THORNYCROFT STEAM VAN.



ANHARD AND LEVASSOR'S DAIMLER
OTOR-CARRIAGE (1894).

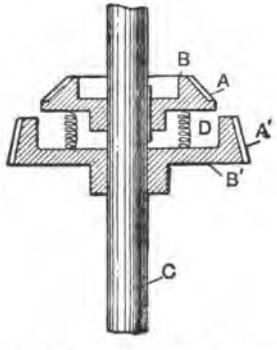


FIG. 22.—PANHARD AND LEVASSOR'S
FRICTION CLUTCH.

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ON

THE USE OF HIGH-SPEED ENGINES FOR MILL DRIVING.

READ SATURDAY, 13TH MARCH, 1897,

BY

MARK ROBINSON, M.Inst.C.E.,

RUGBY.

It is impossible that the great development of the high-speed engine for electric lighting purposes, during recent years, should fail to re-act in some degree upon mill practice, nor is it probable that builders who have achieved success in a field which they consider not less difficult than mill-driving, should remain without ambitions towards what every one must regard as the highest and most famous branch of the engine-builder's art. The high-speed engine begins to seek recognition, as a friendly rival, from the mill engine builders of Lancashire, and although it must be for many years but a humble competitor, its approaches are not unworthy the consideration even of the men who, with their predecessors, have for the greater part of a century led the world's practice in steam engine design.

That speeds have already largely increased in mill practice is undoubted. The higher class of work, and the greater nicety of design, which accompanied the introduction of the Corliss system—a system which involved so many other things than valves and trip-gear—made higher speed a possibility. The introduction of the vertical type of marine engine had further influence in the same direction, and the general result has been a speed of rotation in mill work which would have alarmed

the old builders of beam-engines. Nevertheless, there is no difficulty in drawing the line between mill-engine speeds, as generally understood, and high speed as it presents itself to an engineer accustomed to electric light work. Negatively, we may define high-speed as something much higher than present mill-engine speed. A positive definition is more difficult. In a 600 IHP mill engine, for instance, what is high-speed?

Disregarding, as foreign to the scope of this paper, the claims of the steam turbine to drive anything and everything at 30,000 revolutions a minute or thereabouts—in comparison with which the engines which interest us to-night may be said to differ only in the rate at which they stand still—it appears to the author that, since in electric lighting it is an object to run as fast as possible, it is reasonable to take as a standard the highest speed found to be practically successful in dynamo driving. This is about 300 revolutions per minute for a condensing engine indicating 600 HP—corresponding, in the same type of engine, with a speed of something over 200 revolutions per minute for 1,200 or 1,400 HP.

A large number of single-acting engines of 600 IHP (but able to indicate more) are in successful use, or are under construction, for driving dynamos at the speed named, viz.:—300 revolutions per minute, and many others have lately commenced to run, or are being made, to indicate from 700 to 800 HP, at about 270 revolutions per minute. So far as the author is aware, there is no proposal (as regards reciprocating engines) to use higher speeds than these; on the other hand, such speeds have proved quite satisfactory in practice, and are known to be suitable even for electrolytic work, where provision has to be made for runs of many months without shutting down at all. It seems not unreasonable therefore to take the above figures as standard high-speed figures, viz.:—300 revolutions for 600 IHP; 270 revolutions for from 700 to 750 IHP; and about 200 revolu-

tions for larger engines of from 1,200 to 1,400 IHP. It will be noticed that they represent, at least as regards the smaller sizes, rather more than three times the speed of present advanced practice in mill-engine work, or perhaps four times the speeds still preferred by many builders of double-acting engines.

The time has passed when it was necessary to defend the position that high speed of rotation is a good thing in the abstract. Its advocates have now only to show that its advantages are not outweighed by drawbacks in other directions. Those advantages need be but briefly touched upon. Amongst them are:—

(*a*) Small size and lightness, involving considerable saving in the cost of foundations and buildings, and in space occupied.

(*b*) Evenness of turning moment, due to the larger number of impulses given to the crank-shaft per unit of time.

(*c*) Reduction of initial condensation, due to the shortened exposure of the cylinder and port surfaces to the temperature of the exhaust steam.

The reality of these advantages cannot be contested, though the extent to which they come into force, and their value in comparison with possible drawbacks, are open to argument, and will need consideration at the proper time. There are also certain other advantages which will be claimed for the high-speed engine later, in the shape of remarkable absence of wear, and freedom from trouble in management. These arise, however, not from the merits of high speed in the abstract, but from the peculiar features of a particular type of high-speed engine; they will not, therefore, be referred to now. On the other hand, it may be pointed out that a fast running engine sometimes helps the design of the mill gearing, by getting rid of large ratios between the rope pulleys, and so of large pulleys themselves, and that it also opens up possibilities of using high-speed

shafting generally, and coupling an engine direct to each principal line. The arrangement of matters outside the engine itself is not, however, within the scope of this paper, nor can the author claim competency to speak upon it.

The disadvantages, in the abstract, of running an engine very fast, will be obvious to engineers accustomed to double-acting engines. Wear on brasses; knocking; increased wear; and ultimate break-down, with the alternative of endless setting-up and adjustment of brasses, is the sequence of ideas which will present itself to an engineer accustomed to large slow running engines: "back-lash" goes far to sum them up. Then from the economic point of view, he will portray to himself a diagram which shows wire-drawing in the steam passages, and a throttled exhaust, or, if these evils be remedied by larger passages and valves, then he will foresee a clearance so large as to be in other ways fatal to economy. Moreover, his well-tried Corliss valve, unless in forms which are Corliss valves only in name, is inapplicable, and he hesitates to believe that equal economy will be obtained by other methods. If given to historical research he will find many complaints of high-speed engines as "steam-eaters," and will learn that high speed was once, *ipso facto*, accepted as proof of wastefulness. In the end he will probably subscribe to the many objections which from time to time have been brought forward, and which may fairly be summarised as:—

(I) Want of economy, through the relatively large clearance due to short stroke; through wire-drawing in passages; and from other causes.

(II) Rapid wear in brasses and other wearing parts.

(III) Consequent frequency of adjustment and general trouble in management.

(IV) Difficulties with lubrication, and hence

(V) Excessive amount of attendance required.

(VI) Noise and vibration.

It must be allowed that this list of evils is a fair deduction from the behaviour of ordinary engines when run unduly fast, and is what might be looked for in a high-speed engine based only upon low-speed models. Needless to say, the successful high-speed engine of to-day is of very different pattern, and the differentiation extends to almost everything about it.

Taking the objections seriatim, let us first deal with (I) the assumed want of economy of steam. A high-speed engine must be, by the nature of things, a short-stroke engine, and if the usual clearance is given in the cylinder, it will bear a larger proportion to the total cylinder volume than if the stroke has a more normal relation to diameter. The port clearance, which is manifestly proportioned to the diameter of the cylinder, and not to the stroke, will suffer a like proportionate increase, when comparison is made with a long stroke engine.

Here, for the first time, it is necessary to cease to speak of the high-speed engine in general terms, and to direct attention to one type of it, viz.: the single-acting engine working in constant thrust," for by adopting this type, the question of cylinder clearance at once ceases to trouble. In a constant-thrust engine it is from the mechanical point of view immaterial how small the clearance is made, for whatever wear may take place in the brasses acts only to increase the clearance, and has no tendency to produce a foul. With much wear, and consequent increase of clearance, economy might fall of, but the answer is that in a good constant-thrust engine the wear of brasses is utterly negligible: that the original cylinder clearance may safely be not more, but much less, than in a slow-running (double-acting) engine; and that, without gross carelessness or mismanagement, this small clearance will not be sensibly increased by wear.

Specialisation has thus begun, though constant-thrust, as will be shown later, is justified by other and weightier reasons

than effect upon clearance. At this point the nature of constant-thrust may be indicated, for the benefit of those not acquainted with it. If in a single-acting engine, taking steam only on the side of the piston most remote from the crank-shaft, care is taken to cushion the piston during the second half of the non-effective or return stroke, the big-end brasses will be constantly pressed against the crank-pin during the whole revolution; there will be similar constant contact at the other end of the connecting rod; and the crank-shaft also will press continuously against the main-bearing brass furthest from the cylinder. There will be no "pull-and-push," nor any change in the direction of the pressures, and since the wearing surfaces never separate from each other, "hammering" becomes impossible; there can be no back-lash, no "lost motion," and as a fact there is practically no wear. No doubt constant-thrust is in a sense constant grind; the surface of the brass is never relieved, though that of the rotating part is out of contact with the brass more than half its time. As the surfaces do not separate there is none of what has been described as the friendly lift that lets the oil in, and undoubtedly brasses which are worked in constant-thrust ought not to be loaded as heavily as the brasses of double-acting engines in which there is more or less back-lash. But given a sufficient surface, there is not only no difficulty with the brasses, but there is a considerable superiority in this respect in the single-acting as compared with the double-acting engine; with fair lubrication there is practically no wear at all, and of course, no fear that a clearance once fixed will be appreciably increased by wear. If these statements be thought startling, the proofs are in the room, but the subject belongs really to a later section of the paper—that touching upon durability, where it shall be fully dealt with.

But if constant-thrust indirectly saves the high-speed short-stroke engine from the reproach of excessive cylinder clearance, and even enables it to turn the tables on its rivals, other means must be found to limit excessive clearance in ports. In engines, such as marine engines, where either slide-valves or piston-valves of ordinary type are used, the port clearances are necessarily great, and when combined with short stroke, the clearance ratio under such conditions becomes very bad. The adoption of the Corliss valve would afford a satisfactory remedy as regards clearance, but at the cost of giving up its best feature, the trip-gear, which, of course, cannot be worked at very high speed. Probably the best valve of all for smallness of port clearance is the Willans "central valve," which is a piston-valve working inside the piston-rod, the latter being hollow; the port clearance is only that due to the thickness of the walls of the tubular piston-rod. This feature, peculiar to one type of high-speed engine, removes all remaining objection on the score of clearance; one high-speed engine at least, though of short stroke, can hold its own under this head with any long-stroke rival, and yet allow ample port area to prevent wire-drawing.

A sounder objection to the high-speed engine is that, owing to its smallness, the cylinder surface is considerable in proportion to the enclosed volume of steam; hence initial condensation tends to increase. The objection would be a valid one, were it not that the high speed of rotation, to which the smallness of the cylinders is due, also reduces the condensation, and in a far greater degree than the relative largeness of the surface increases it. It is by reduction in initial condensation that the best examples of high-speed engines achieve their remarkable economy, *i.e.*, through the shorter exposure of the cylinder surfaces to the cooling effect of the exhaust at each stroke, and then through the shorter exposure of the incoming steam to the surfaces thus cooled; the surfaces

are cooled less, and the hot steam is exposed to them for a shorter time.

Explanations of causes have their interest, but as the present object is mainly to show the groundlessness of the view that high-speed engines are necessarily uneconomical, it will be better arrived at by recording the result of an actual trial of a triple expansion high-speed mill engine, tested after about six months' working. The figures have been published before, but they will bear repeating, and they are printed in Appendix A, together with the report of the consulting engineer who conducted the trials, Mr. A. Basil Wilson, M.Inst.C.E., of Hollywood, Belfast. The engine tested is described in Appendix B. It is intended to indicate about 500 IHP, and it has driven the flax mill of Messrs. Gunning & Campbell, Limited, of Belfast, for about three years past, without hitch or accident; the steam consumption was fractionally below 12·5lbs., per IHP per hour. This engine has been referred to because it is the first Willans engine constructed, belonging to what is called the new series, *i.e.*, engines specially designed for condensing work, with cylinder ratios based upon the results obtained by the late Mr. Willans shortly before his death, in his well known experiments upon the economy of high-speed condensing engines. It may be remembered by those familiar with his posthumous paper on "Condensing Trials," read before the Institution of Civil Engineers in 1898, that figures nearly as good as those of the Belfast engine were obtained with a little engine indicating less than 80 HP, with which the trials were carried out. In view of figures such as these, and of the experience gained with many hundreds of central-valve engines running for years past in numerous electric light stations and other places, it is obvious that the charge of want of economy against high-speed engines cannot be maintained, and that under this head they may justly claim an equal place with the best types of slow-running engines.

It cannot be doubted, however, that the economy of the high-speed engine is not generally accepted in the North. A northern electrical engineer, speaking recently in this room, of course of dynamo driving, said "as to the economy of rope-driving over direct-driving *there could be no question*," that is to say, he made the direct-coupled and presumably high-speed engine a present of the power lost in rope-transmission—five per cent., or more probably ten per cent., when extra bearing friction is taken into account—and supposed the Corliss engine to be even *then* greatly superior in economy to the other. As a fact the Author has never been able to hear of a rope or belt driven plant in which the combined efficiency came within some ten per cent. of that of the best direct-coupled sets, and where it has been possible to obtain figures of actual steam consumption per unit of electrical power produced, the difference in favour of the high-speed engine has been greater. The assumption that direct-driven plant is only used in cases where space is more valuable than economy (for the "extra annual cost of running" the direct-coupled plant is treated by the speaker referred to as though every one accepted it) is calculated to astonish nineteen out of twenty of the Electrical Engineers of Great Britain, including those responsible for the lighting stations of such cities as Liverpool, Bradford. Birmingham, Brighton, Bristol, Hull, Edinburgh, Glasgow, and many other first-rate towns. Even in America, the last home of belt driving, it is becoming obsolete, and nothing but direct-driven plant is projected for important stations, while the same view, if the Author is not mistaken, now obtains amongst the engine-builders of Lancashire, though the engines they couple direct are low-speed and not high-speed engines.

The second and third heads of objection, viz., that the wear of brasses and other parts is necessarily rapid in high-speed

engines, and that in consequence there must be frequent adjustment and much trouble in management, will be better dealt with last of all. These are the real points which interest engineers; minor matters may be disposed of first.

Passing to (IV), alleged difficulties with lubrication, it is perhaps sufficient to say that no engine runs with such absence of lubrication trouble as the high-speed engine of the constant-thrust type, since it wholly lubricates itself. The cranks and big-ends actually dip into an oil bath at every revolution, and splash the lubricant copiously into the guides and over the main bearing brasses. There is nothing further for the attendant to oil, except a few pins, &c., about the governor.

The advantages of the closed crank-chamber can be thoroughly enjoyed only with a constant-thrust engine, at least if very long runs are contemplated, for it is, or ought to be, a condition of its use that there must be no frequent necessity for adjustment of brasses. Another condition of its successful employment is that, like every other speciality, its idiosyncrasies must be considered. No system of lubrication can compare with it, either for convenience or for economy of oil, but it suffers from the drawback that a bad quality of oil, which in an open engine may mean only the use of a larger quantity, may in a closed engine involve comparatively serious trouble.

With such good facilities for lubrication, it need hardly be said that the charge (V), that an excessive amount of attendance is required, is very wide of the truth indeed. The testimony from scores of lighting stations is unanimous on this point. In one station, where there is a row of eight large Willans engines, indicating 700 HP. each, direct-coupled to alternators, and where all the eight may frequently be seen in use together, the whole engine-driving staff attending upon these engines, in the season of maximum lighting, is but *three men*, including day and night

shifts. During the busiest hours there are two men; at other times one. There are of course electricians and dynamo attendants besides, but they have nothing to do with the engines. It will probably be allowed that this case disposes of the objection that high-speed engines "want such a lot of looking after." It would be easy to adduce similar testimony from a large number of other stations.

The last of the assumed charges viz:—(VI) that high-speed engines produce much noise and vibration, is now so widely known to be untrue, that few words need be wasted on it. It is evident that an engine which has no back-lash, and cannot have any, even if wear has taken place, must run more silently than other engines, and the more scientific study which the question of vibration has received of late years, from the Author's colleague, Captain Sankey R.E., and from others, has greatly changed the views of engineers as to the causes of vibration. Under many circumstances rapidity of revolution is now recognised as an aid in breaking up, and so neutralizing, the vibrations due to the inertia of the moving parts.

To revert to objections (II) and (III), viz.: that with high-speed there must necessarily be rapid wear in the brasses, and in the wearing parts, and consequently frequent need for adjustment and repairs—it will be best to deal with these by the evidence of actual cases. The reasons why high-speed engines (if working in constant thrust) should not, in the opinion of their advocates, develop abnormal wear, have already been given, but they may be summed up again as, first, perfection of lubrication; secondly, continued pressure between the brasses and the journals or crank-pins, so that they never separate, and therefore never come together again; in other words can never commence to hammer each other. As reasons, these are certainly valid ones, but it is reported in the South that what a Lancashire man wants is *facts:* that reasons without facts are little valued by him; and

that even the best attested facts are more kindly regarded if he is in a position to examine them for himself.

To begin with facts which are but attested facts, and which you cannot examine for yourselves, let us take a single-acting high-speed engine, No. 906, indicating 80 HP, which was started to work in April 1890. It was coupled directly to a dynamo, the normal speed being about 400 revolutions per minute. It ran every day, for about 14 hours a day (Sundays included) in the electric lighting service of one of the largest London Hotels, and until March 1895—five years, all but a few days—it was never even taken down for examination. At last, at the time named, and after making some six hundred million revolutions, more or less, it was ordered to be taken down for an overhaul—and this is the report on it:—

> "All the parts were carefully measured, and the H.P. and L.P. trunks showed no perceptible wear, and were replaced the same as they were taken out. On measuring the H.P. Cylinders we found they were $\frac{2}{1000}$ths. of an inch larger than our standard size, and L.P. Cylinders were the same; still they were quite round. All piston-rings and gland-rings were replaced without any repairs whatever. The whole of the repairs to this engine, including taking down and re-erecting, were executed in 24 hours."

In 1892 two engines were put down in Bolton, one to indicate 650 HP, and the other about 500 HP: both drive cotton mills. They were the first large Willans engines made, and they were designed before the condensing trials, previously referred to, had been carried out by Mr. Willans. The ratio between the cylinder diameters was eventually increased, in consequence of Mr. Willans' experiments, in order to carry the expansion further. Apart from this change the engines have always run well, though the larger engine, No. 1,253, of 650 IHP,

unfortunately broke its crank-shaft within the first year of working, from causes not connected with the questions now under discussion. It was taken down for examination in 1895, having had just upon three years' work. The complete dismantling, thorough examination, and getting ready for steam again, lasted from Thursday evening to Sunday afternoon, including some hours' delay due to the accidental breaking of a stud. Beyond replacing this, there was absolutely no repair of any sort done, and the Boiler Insurance Society's Inspector who examined the engine, reported as follows :—

> "The cylinders were taken down and pistons and valves out, which are 17in., 28in., and 40in. diameter, with 1ft. 6in. stroke. Revolutions 206; boiler pressure 160lbs. I examined and gauged all the six cylinders with a very fine gauge, one that can be set to $\frac{1}{10000}$ part of an inch, and found H.P. cylinder about $\frac{1}{1000}$ part of an inch worn; I.P. cylinder $\frac{1}{3500}$ part, and L.P. $\frac{1}{7000}$ part of an inch worn; indeed the tool marks had not properly worn out. The surfaces as smooth as glass. The pistons and rings, which are Mather's design, seem to be very good, all bearing well round; the piston rods or trunks also appear to have good surfaces, also internal surfaces where the valves work seem good, and the rings of the piston valves also appear very good, so good that they scarcely appear to have been at any work."

The other Bolton engine, of 500 IHP, has been taken down recently, after nearly five years running, and this is how it was reported upon :—

> "At the time of our Inspector's visit the left-hand engine had been taken apart, and he found the several details to be in very good condition without perceptible signs of wear or ridges."

"The HP. cylinder gauged 15·004in. with no perceptible difference in the several parts. The IP. cylinder gauged 24·006in. to 24·0075in. The LP. cylinder gauged 34·004in. to 34·0045in. You will observe that these dimensions are greater than the nominal diameters of the cylinders by about $\frac{1}{200}$ part of an inch."

"We have no information as to whether the cylinders were originally of the correct diameters, but if they were so the amount of wear which has taken place is very small for five years' work."

"The intermediate piston rings were slack between the body and the junk ring. The others were in good condition. The trunks were in good condition all over, showing no signs of wear, but were to be replaced by others giving larger steamport openings."

With reference to the remark in this letter as to the original diameter of the cylinders, it may be said with certainty that the cylinders could not have been less than the number of full inches stated, or they would not have gauged. But they may have been, and probably were, *larger*: if so the wear *is less even than that assumed.*

Partly in consequence of the increase in the expansion ratio, before mentioned, it was desired on this occasion (as stated above) to cut certain new steam ports in the trunks, or hollow piston rods, and they were removed for the purpose, another pair of trunks, out of another engine, being lent in place of them (this shows both the reality and the advantage of the system of interchangeable parts). To place before you facts of the kind which every man may test with his own eyes and hands, the author has asked, and has received, permission to show here both the removed trunks, which have been running for nearly five years. The place to look for wear is where the path of the gland rings ends; here we might expect some difference of diameter between

the part which works through the rings, and that which remains outside. It is a hard matter for the finger to feel it. The same ring gauge originally used for these trunks is here, and you will notice that it is still a perfect gauge fit. There is really no ascertainable wear whatever, after (it is estimated) at least 320 million strokes. The grinding marks are still on the trunks. A steam gland of the kind used with them, and similar to those through which they have worked for five years, is also here for inspection.

To enable him to place before you still other evidence of the same order, the author has obtained the kind permission of the owners of the same engine to take out the main bearing brasses, and two pairs of the big-end connecting-rod brasses. These were taken out yesterday evening, the engine starting as usual this morning with other brasses taken out of store. In order that you may see what wear results from five years running, Gauges are provided by which the wear may be tested.

As a fact the wear is as follows—that is, the worn brasses show the following reduction in thickness as compared with the unused spare brasses shown with them :—

	Inches wear.
Main bearing brass, fly-wheel end	·065
,, ,, centre	·074
,, ,, governor end	·071
Big-end brass, No. 1	·057
,, ,, No. 2	·031

The *average* wear in five years is, therefore :—

Main bearing brasses	·070
Big-end brasses	·044

But it must be remembered that the white metal compresses a little on the first running of the engine, and this perfectly normal reduction of thickness, which is not wear at all, is included in the figures given. Moreover, some years ago there was a lubrication trouble in this engine, and the white metal of

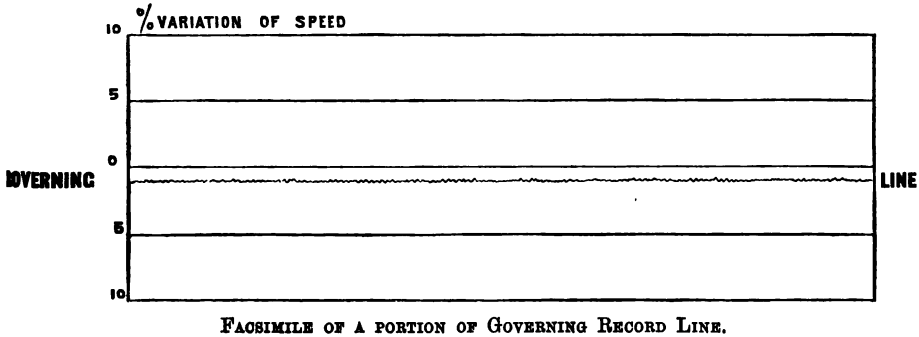
one bearing brass began to run. The brasses were taken out and scraped, and put back, and the loss of thickness due to this operation is also included in the above figures. The reduction of thickness due to wear alone is small indeed for five years' work, and it is only to be regretted that the crank-shaft journals and the crank-pins, which have made so many millions of revolutions in these brasses, cannot be exhibited with them. Their condition is said to be perfect, with a polish like glass.

You will doubtless agree that the durability of the high-speed engine, and its immunity from serious wear, are now placed not only beyond controversy, but in a position whence its friends may challenge the makers of double-acting engines to produce results equally good. Such a challenge would not, of course, be addressed to makers of the very slow-running beam-engines of fifty years ago, in which surfaces were so enormous and pressures so light that extraordinary durability was attained: but it might well be addressed to those who still believe the high-speed engine to be inferior in durability to other modern engines working at modern speeds, and with modern pressures. If seeing is believing they can believe so no longer.

In the author's opinion the remarkable results just laid before you are due to the engines working *in constant thrust*—that is to say, they are not only single-acting engines, but they are single acting for the purpose of securing, and with the result of securing, the continuous pressure of the brasses against the rotating surfaces. The complete success of this system in preventing wear is consonant alike with theory, and, as you see, with practice, and the author finds it hard to believe, unless on the evidence of very much longer experience than has yet accumulated, that any perfection of workmanship, or any abundance of lubrication, will permanently overcome the tendency to wear in the brasses of very fast-running engines, in which there is reversal of pressure at the end of every stroke.

Before leaving this point it should be remarked that even if the wear in the mill-engine brasses exhibited this evening had been many times as great as it is, it would have produced no effect whatever upon the running of the engine; there would still be no back-lash, and no hammering; in fact the brasses might almost wear through before there would be real necessity to attend to them. This is another advantage in the constant-thrust engine, even though, as we may hope, it may rarely be called into play. For constant thrust there may in fact be made the almost paradoxical claim, that it first prevents wear, and then makes wear innocuous. It is the first half of the claim which is the more valuable.

The work of answering objections has lasted too long to admit of much being said on the special advantages claimed for the high-speed engine at the commencement of the paper. The first, smallness and lightness, and saving of space, is generally recognised, but it is doubtful if many realise how great is the gain in regard to cost of buildings and foundations. Evenness of turning moment is a question which needs a paper to itself; it is sufficient to refer to the annexed reproduction of a speed-recorder diagram, taken from the mill engine referred to in the Appendices A and B. This will suffice to show what a high-speed engine can do in regard



FACSIMILE OF A PORTION OF GOVERNING RECORD LINE.

to regularity of running. The third claim, smallness of initial condensation, has to some extent been dealt with already.

In illustrating various points the Author, though desirous to write in general terms, has been compelled to refer continually to the particular type of engine in which he is himself interested, because it is the only exemplar on a large scale of many of the features to which he attaches value. Success, in a commercial sense, is not the best test of merit, but it is difficult not to see significance in the fact that the new works in which this engine is henceforth to be made, will begin operation next week with some 40,000 IHP in hand. These engines are not the choice of private owners, except to a very small extent: they have been selected by engineers, and mainly by engineers who have had the same type of engine running for years under their own observation. In trying to show that the high-speed engine has a great future before it, and that it deserves a recognition not yet accorded to it in the North, the Author trusts he may be forgiven for his many references to the Willans engine; he only wishes that the circumstances of the case permitted an attempt to do justice, not only to the engine, but to the fame and the work of that distinguished man of genius, himself a son of the North, who step by step elaborated its remarkable design, and who used it to such good and disinterested purpose for the advancement of scientific knowledge, giving the benefit of his researches to all engineers alike, while claiming no credit for himself. Witness has been borne to the greatness of Mr. Willans' work in many places, and by men of an eminence the Author cannot pretend to, but the subject must not pass unmentioned in a paper which owes any vitality it may possess to the Willans engine alone.

The Author, a stranger in the land, can only thank you for your great kindness in inviting him to read this paper. He does not forget that in one sense, a paper upon high-speed

engines in mills bears some analogy to that more famous, and far briefer, paper upon snakes in Ireland, which was limited to the statement that there are no snakes in Ireland. That, you may think, is almost as much as need be said about high-speed engines in mills: they are almost as rare as the snakes of Ireland. But there is a distinction; the snake, so far as is known, has no ambition to go to Ireland, whereas the high-speed engine is ever widening its borders. But whatever your verdict on its claim to consideration as a mill engine, the Author regards it as certain, that, with the catholicity which marks true engineers, and with the liberality which distinguishes the men of your famous city, you will not fail to extend to it the welcome of a friendly though discerning criticism.

APPENDIX A.

ECONOMY TRIAL OF A TRIPLE-EXPANSION WILLANS CENTRAL-VALVE ENGINE.

COPY.] HOLLYWOOD, BELFAST,
9th February, 1895.

To Messrs. Gunning & Campbell, Limited,
North Howard Street, Belfast.

DEAR SIRS,—I have pleasure in sending you herewith the report of the test of your steam engine and boiler carried out on 4th October, 1894.

The object of the trial was, in the first place, to ascertain the weight of steam used per horse-power, and the steadiness of running of the engine erected by Messrs. Willans and Robinson, Limited, under contract dated the 7th day of April, 1893, by which they engaged that while indicating from 300 HP to 350 HP the duty of the engine would be a consumption of not over 13lbs. of dry steam per IHP per hour, at 175lbs. steam pressure per square inch in the steam chest, and that the governor gear should be so arranged that between full and half load the speed should not vary more

than 1 per cent., and between full and no load not more than 10 per cent. And, in the second place, to determine the general efficiency of the plant.

ENGINE.

The Engine is a triple-expansion condensing Willans Patent Central-valve Engine, having three cranks and three lines of cylinders; the high-pressure cylinders of each line being of 300 mm. diameter (about 11·8 inches), the intermediate 480 mm. (18·9 inches), and the low pressure 720 mm. (28·3 inches). The stroke is 260 mm. (10·24 inches), and the revolutions are intended to be 300 per minute.

An extension of the crankshaft carries a flywheel grooved for 18 cotton ropes 1¾ inch diameter, the pitch diameter of groves being 5 feet; from the flywheel the power is distributed to the various shafts in the mill.

The air and feed pumps, of which there are two, are driven from one of the mill shafts by ropes, the air pumps being each of 1 foot 6½ inches diameter and 9 inch stroke, and the feed pumps 2⅝ inch diameter and 6 inch stroke, all single acting and running at 90 revolutions per minute.

All the measuring instruments were carefully gauged immediately after the trial, which was conducted by me, on behalf of the owners, with the assistance of Messrs. W. Grant, P. Nicholson, S. Guildford, and Mr. W. Scott, the Engineer of the Company; and, on behalf of the makers, by Captain Sankey, R.E., Mr. P. A. Low, Mr. R. Todd, and Mr. J. Ramsey.

Crosby indicators were used throughout, and standardised thermometers and mercurial vacuum gauges.

As the mill is under the Textile Factory Regulations, the longest period through which a test could be conducted was 4½ hours in the forenoon and 3½ hours in the afternoon. As a check on the correctness of the trial, separate records were kept of the consumption of steam, coal, &c., for running as well as standing starts; that is to say, in the one case the total number of revolutions was taken from start to stop, and the level of the water in the boiler carefully measured before and after the engine began to move; in the other case, the corresponding records were taken after the engine had attained full speed, and before its speed was reduced for stopping.

During the trial all flanges of pipes not in use were blanked off, and the various leakages from safety valves, &c., were carefully weighed.

The water used was measured by a self-acting apparatus, of which the error was found to be under 1 per cent.

The indicator diagrams were worked out by four independent observers, and the average of their results was taken.

No test was taken of, nor is there any deduction for, priming, which was practically nil. This may be assumed from the fact that the deductions to be made from the total feed for all causes, including the separator drain, leaks in safety and economiser valves, &c., as well as the priming, amount to only about 2¼ per cent. The water caught in the separator, which affords the nearest estimate of priming, but which includes condensation in the steam pipes, was only about ¾ per cent.

BOILER.

The steam was supplied by one Lancashire boiler, 7 feet 6 inches diameter, with two Purves flues, each 2 feet 11 inches diameter, having a grate surface of 32 square feet and a heating surface of 904·5 square feet, and working with an economiser having 192 tubes and approximately 2,304 square feet of surface exposed to the escaping gases, as well as to those of a low-pressure boiler 7 feet 6 inches diameter by 30 feet long, and burning about 130lbs. of coal per hour.

Steam pressure in the boiler was easily maintained, and the conditions of working were in all respects the same as during the ordinary running of the mill. Neither engine nor boiler was specially opened up or examined; the former had been running for the previous five months.

A second boiler which supplied the engine was blanked off during the trial, and stood empty and cold, with its mud door off.

The coal used was "Vivian's Welsh" through and through, weighed out in bags on the stoking floor, and its value was found by experiment* to be 13,200 B.T.U. per lb. The clinker and ashes passed through the bars were weighed after the trial, but no attempt was made to separate the combustible portion from the incombustible.

The time of using each sack of coal and tank of water was kept and plotted.

With regard to the coal consumption, including getting up steam, loss at meal hours, at night, and on Sundays, the average had been approximately 15 tons per week; but it must be borne in mind that the horse-power does not reckon so high for the whole period. Each Saturday a quantity of machinery is thrown off, and in the mornings the engines are run lighter than through the latter portion of the day.

* Determined by William MacNab, Esq.. as the mean of three samples.

Indicator diagrams were taken throughout the trial from all cylinders simultaneously at intervals of 15 minutes, and at the same time records of temperature, &c., were obtained.

The variations of speed were ascertained by a recording instrument made specially for the purpose, showing variations of one-tenth per cent. in the speed; the record being obtained from a specially-designed governor running normally at 500 revs. per minute.

GENERAL RESULTS.

The mean IHP of the four trials was 394·7, with an average mean pressure, referred to the LP cylinder, of 28·9lbs per square inch, the average revolutions of the running start trials were 300·75 per minute, the mean pressure in the steam chest being 169·5lbs. The mean vacuum was 25·9. The steam used, after deducting leakages, was, for the mean of the four trials, 12·49lbs. per IHP per hour, and for running start trials 12·44lbs. per IHP per hour.

Seeing that the level of the water in the boiler was steady, I am of opinion that the *flying starts* are somewhat more accurate than the *standing starts*, as the flow of steam was practically uniform.

The variation in speed was approximately ½ per cent. The coal used on the trial was 1·185lbs per IHP per hour, or, with the ashes and clinker deducted, 1·002lbs. per IHP per hour.

The water evaporated from a feed temperature of 113 degs. was 11·1lbs. per pound of coal, or from and at 212 degs., 12·83lbs. per pound of coal.

The principal results of the trial will be found below. It is to be regretted that the conditions of the case were such as prevented a longer running period, as possible errors in estimating the quantity of coal on the bars would have been reduced. In respect of this element of uncertainty, the water evaporated per lb. of coal may be inaccurate either way to the extent of 3 per cent.

I am, Yours faithfully,

A. BASIL WILSON.

Test of Willians Engine at Messrs. Gunning & Campbell's Mill, Belfast, October 4th, 1894.

Duration of tests: 1st, 4·2916; 2nd, 3·5166; 3rd, 3·55; and 4th, 3·05 hours.

Effective area of Cylinders—three of each: High-pressure, 90·836 square inches; Intermediate, 345·44 square inches; Low-pressure, 587·175 square inches.

Stroke: 10·24 inches.

Number of Boilers in use	One.
Total length of Boiler	28 feet.
Diameter of Boiler	7 feet 6 inches.
Diameter of Furnaces (two)—(Purves mean diameter)	2 feet 11 inches.
Heating Surface of Boiler	904 square feet.
Grate Surface of Boiler	32 square feet.
Ratio of Heating Surface to Grate Surface	28 : 1.
Mean Boiler Pressure above the Atmosphere	190lbs. per square inch.
Mean Admission High-pressure Cylinder	169·5lbs. per square inch.
Mean effective Pressure on Low-pressure Cylinder	28·918lbs. per square inch.
Mean Vacuum	25·925 inches.
Mean Revolutions per minute	299·8.
Mean IHP	394·775.
Mean total Feed-water per hour	5,050lbs.
Mean Deductions for Separator and other Drains per hour	117·1lbs.
Mean total Steam to Engine per hour	4932·9lbs.
Mean Steam used per IHP per hour	12·49lbs.
Temperature of Feed to Economiser	113 degrees.
Temperature of Feed to Boiler	243 degrees.
Coal burnt per hour	457·6lbs.
Coal burnt per square foot of Grate Area per hour	14·3lbs.
Coal burnt per IHP per hour	1·185lbs.
Pounds of Water evaporated per lb. of Fuel	11·1.
Pounds of Water evaporated per lb. of Fuel from and at 212° F.	12·83.
Pounds of Water evaporated per square foot of Heating Surface per hour	5·58

(*Signed*) A. BASIL WILSON.

APPENDIX. B.

DESCRIPTION OF A WILLANS TRIPLE-EXPANSION CENTRAL-VALVE ENGINE.

The engine is single-acting, and on the "constant-thrust" principle,—that is to say, the connecting-rods are always in compression; never in tension. All the brasses are held close together, both upon the up-stroke and upon the down-stroke. The latter is the working or effective stroke: during the first portion of it the steam pressure on the pistons presses all parts against the cranks, and the crank-shaft against the lower main-bearing brasses; in the latter portion of the down-stroke the inertia of the parts, as they are brought to rest by the changing angle of the crank, also help to keep them in compression. On the up-stroke, when no work is being done, and when the steam is being merely exhausted from the several cylinders, the inertia of the parts as they undergo acceleration by the crank also keeps them in compression for the earlier portion of the stroke; in the latter portion they are cushioned by the arrangement to be afterwards described. The result is that in no part of the stroke, up or down, do the parts tend to separate; consequently there is total absence of "back lash" or "lost motion," and "knock" cannot arise, as it would if the engine were double-acting, particularly in view of the high speed adopted.

The figure shows a triple-expansion condensing engine in section (through one line of cylinders). The steam is distributed throughout by the hollow piston-rod R (sometimes called the "trunk"). It enters from the steam-chest by the oblique cut-off ports, shown near the top of the piston-rod. By the movement of the line of piston valves, which work inside the piston-rod (driven by the eccentric shown), the steam passes into the HP cylinder, at the beginning of the stroke, by the holes of ports shown just above the HP piston. It is important to remember that this ring of ports is the only inlet to and outlet from the cylinder, and that it moves up and down with the piston.

The valve gives just the same steam distribution as an ordinary slide valve, with a slow cut-off at about three-quarter stroke, or a little later. The actual cut-off is, however, effected by the oblique ports in the steam chest, which, at a point in the stroke either pre-arranged in the design of

the engine, or controlled by the governor, pass behind rings, or a sleeve, so disposed as to prevent the further supply of steam for that revolution. As the cut-off motion is the same as that of the pistons themselves, the cut-off is very prompt, and shows a sharp corner in the diagram.

After the steam has worked expansively in the HP cylinder, the valve passes above the ports and opens communication from the working end of the cylinder—*i.e.*, the space above the piston—to the space below it, which is called the HP receiver, but which is equally a steam chest for the IP or intermediate cylinder. During the up-stroke the steam is simply transferred from one side of the piston to the other; the whole cylinder, including the "working end," at that time forms part of the receiver.

When the next down-stroke commences, the steam in the HP receiver is passed into the IP cylinder. It enters the hollow piston-rod again from the receiver by the ring of short square-headed holes shown, and passes from the piston-rod to the cylinder by the ring of ports shown just above the IP piston. Cut-off in this case is given by the square-headed ports passing into the gland in the IP cylinder-cover, and so losing the supply of steam from the HP receiver (=IP steam chest). The cycle is exactly the same as already described from the HP cylinder, and at the end of the *second* revolution the steam fills the IP receiver. Thence, in the *third* revolution, it passes into the LP cylinder; and in the second or exhaust, half of that revolution, it passes from the LP cylinder—*i.e.*, from its upper end to the lower end, of course without material change of volume or pressure. It is only during the first half of the *fourth* revolution that it finally passes away from the "transfer chamber" to the "exhaust chamber," the latter being in permanent communication with the condenser.

The full cycle thus described is that of a *triple-expansion Cornish engine.* In each separate stage of the expansion the complete Cornish cycle can be traced, and it is evidenced by two separate diagrams from the upper and lower end of each cylinder. The diagram from each receiver, or from the "transfer chamber," represents (as in every Cornish engine) the removal of back-pressure on the down-stroke, forming a virtual addition to the diagram from the upper end of the cylinder. The advantage is that the total range of temperature due to each stage of expansion does not take effect in the working cylinder, but only part of it. Part of the temperature range acts in the receiver only, where it does little harm; the limitation of the temperature range in the working cylinder is, of course, a clear gain in the matter of initial condensation.

The cushioning arrangement is special to the Willans engine. The guides take the form of bored cylinders, and the cross-heads are pistons, without rings. The top of the guide cylinder is closed, and on the up-stroke the air in it is compressed to the extent necessary to cushion the pistons and other parts. The power stored in the air by compression on the up-stroke is given out again during the immediately succeeding down-stroke, without sensible loss

In a compound engine there are but two cylinders in series, but the "cycle" in each is precisely the same; in a simple engine only one. More usually the final "transfer chamber" is omitted and the steam exhausts directly from the working (upper) end of the LP cylinder into the condenser or atmosphere—*i.e.*, the lower end of the cylinder is in permanent connection with the exhaust.

The line of valves is driven by an eccentric *on the crank-pin.* It is necessary that the source of motion for the valves should itself move up and down with the pistons, since the ports which have to be opened and closed also move up and down. There is an eccentric rod, which takes on to a hardened pin in a valve guide-piston; the latter works in a bored guide, formed inside the main guide-piston.

There are two connecting-rods to each line of pistons, one on each side of the eccentric; the eccentric rod plays between them.

The cranks and all working parts, except the cylinders and valves, are lubricated by the splash of the cranks in the crank-chamber, which contains a mixture of oil and water. The guides and the pins at the upper ends of the connecting-rods and eccentric rods are readily reached by the splash.

The cut-off in the first or HP cylinder is effected, as before stated, by the movement of the ports in that part of the hollow piston-rod which projects into the steam chest. Where the engine has an invariable expansion, the cut-off ports, as they are called, are of the same shape as those for the succeeding cylinders, and they lose their supply of steam by merely passing into the gland which separates the HP cylinder from the steam chest. If early cut-off is desired, the gland itself is raised a little by packing pieces between it and the cylinder top. In that case the ports enter the gland earlier, and cut-off is earlier.

Where the expansion is made variable, either by hand or by the governor, inclined ports are used, and the upper end of the piston-rod is surrounded by a sleeve, which also has inclined ports in it. The sleeve is capable of a certain amount of rotation, which causes the ports in the rod to be covered

(by the solid part of the sleeve) earlier or later. In the latter patterns the sleeve is suspended by a spindle which passes through a gland in the top of the steam chest, and the spindle is rotated by suitable links, &c. These are moved by hand, or by a relay cylinder, the action of which is controlled by the governor.

It will be noticed that in the figure there is a hollow space in the casting under the bottom of each receiver. This is supplied with steam, and acts as a jacket, passing heat into the upper part of the working cylinder, and serving to re-evaporate, in the receiver, the water which may enter it from the preceding cyllnder. The latter engines are without this jacket arrangement. Like all attempts to improve the Willans engine by jacketing, it has been unsuccessful. It reduces the consumption of steam in the cylinders per IHP, but the weight of steam condensed in the jackets just equals that which is saved in the cylinders. Apparently, a high-speed engine, *with good natural drainage* and ample sub-division of the total range of temperature, suffers too little from initial condensation to be capable of improvement by jacketing.

DISCUSSION.

Mr. Alfred Saxon said that in the North they were rather in a transition state on the question of high-speed engines, and only needed leading in the right direction. They must not forget that in the North the piston speeds were often higher than those of the Willans engine itself.

With regard to this engine, it might be asked, "why did not they get better results from it, with all the advantages claimed in the way of small initial condensation, small cylinder clearances, owing to the central valve and to the fact of the steam being exposed a shorter time, both so far as initial condensation and condensation due to the action of the exhaust were concerned?" The only reason he could suggest was that they had that action repeated so much oftener than in a slow running type of engine.

He doubted the results of the Irish test.

Speaking generally the Willans engine was one well worth their notice, and was constructed in a manner which was calculated to call forth admiration from all engineers. He did not suppose there was another engine that would stand the examination which the Willans would after the same time of running.

The author had said nothing about the cost per IHP as compared with a Lancashire mill-engine, which a purchaser would be obliged to ascertain.

He thought that when these high speed engines came to be tested more in the way in which engines were generally tested, in the ordinary working of the mills, the results would be only equal to the average Lancashire mill engine.

He had in his hand diagrams taken from a Willans engine, boiler pressure 160lbs., which showed for a week's running, including banking of fires, steaming of mill, etc., a consumption of 2·6lbs. of coal per IHP; an average compound mill engine at 100lbs. pressure would do that, which was nothing remarkable. He had an idea, however, that the engine referred to was built before the condensation trials, and the one in Belfast would no doubt be much nearer the present type, which the paper dealt with.

Mr. JAMES HARTLEY asked what was the boiler pressure at Belfast (Member: 160lbs.), well, the result was not so good; he knew of a compound engine in Ireland of the tandem type, with a surface condenser, and had found that with 125lbs. boiler pressure it used under 14lbs. of water per HP per hour. The revolutions were 69 per minute and the stroke 4ft. This compared very favourably with the 500 HP engine at Belfast.

He supported Mr. Saxon's remarks about piston speeds.

He agreed with the author as to lubrication. He had once had occasion to see a Willans engine that had broken down,

and on taking off the cover, found that owing to the bad quality of the lubricant used, it had been beaten up into something like glucous putty. No wonder the engine had broken down, and it was attributed to the high speed at which it had run, but when they came to examine it minutely, it was found to be choked up with the sort of matter described.

In mills, driving each room independently would be far the best plan, and although our Lancashire makers did not believe in this but trusted in big engines of 1,500 to 2,000HP, he thought the time would come when we would have smaller engines, driving certain portions of the mill, and do away with the larger engines as at the present day. We should then get more economical results than were now obtained.

Mr. HENRY HODGSON said, from the reading of the paper, the whole case of the high speed engine was stated in the three sub-sections A B C on page 135, as against the slow speed engine. By this he meant high revolution speed as against comparatively slow revolutions, because in point of fact, the piston speed of the latter in good practice was higher than the engines forming the subject of the paper. The remainder of the paper contained the arguments by which the author sought to substantiate the claims he sets forth in the sub-sections before named. Dealing with the first, was it not a fact that the capital cost of a Willans and Robinson engine of given power, including buildings and foundations, was as much as ordinary Engineers require for the slow running engine, including buildings and foundations? This might be that the makers of the high speed engine sold their work for more than it was worth, but at present he believed the fact was as he had stated.

Dealing with the second clause, as to evenness of turning, it must undoubtedly be conceded that the greater number of impulses given to a shaft in a specific time the nearer perfect

would be the turning, but in practice it was found that a three crank engine making 80 revolutions per minute, equal to 480 impulses per minute, gave sufficiently near perfect turning to meet all practical requirements of the Cotton Spinner. Even the driving by a steam turbine, not to say a Willans & Robinson Engine, would give no material advantage, and he therefore thought the advantage claimed by the author was not worth much.

By the third clause he understood the author to claim that in consequence of the shorter time the cylinder was exposed to cooling influences, that the result would be a more economical engine. This might be claimed, but he was very much inclined to think that it had by no means been proved. He saw that it was stated in the results of the trial of the engine supplied to Messrs. Gunning & Campbell's, of Belfast, that the engine used 12·49lbs. steam per IHP per hour. Well, without saying that this was inaccurate, there are some other statements made in the particulars of test that led him to think that all that was there stated need not be accepted without question; but granting it, was it any better than could be got out of the slow revolution engine. The firm of which he was a member also made a triple expansion engine for Belfast at about the same time; this engine was also guaranteed to work with not over 13lbs. of steam per IHP per hour; this engine was also, he presumed, tested, at any rate when the final payment was made. He enquired about the consumption and the reply was that it was satisfactory, but this did not exhaust the question. The engine referred to (Gunning & Campbell's) was evidently intended to drive 300 to 350 IHP, as stated in the terms of the contract on page 151, but, in fact, when the test was made was indicating 394. He thought it was reasonable to suppose that in fixing upon 350 IHP the owners would be fixing upon a power certainly not less than was being driven by the beam engines

previously driving the mill. If this be so, does the change from gearing to rope driving accounts for the difference. In a very similar case, where a pair of beam engines and a horizontal engine were replaced by a set of three crank inverted vertical engines, running at 100 revolutions per minute, the driving also being changed from gearing to rope driving, the result was a reduction in power. Again, it had been his privilege to have to do with the beam engine driving a mill in Bolton which had been replaced by a high speed engine. This engine was stated in the paper as being of 650IHP; well, the old beam engine indicated something less than 500; where was the difference in the power? (A member: The mill has been made larger, eight more cards and four more mules.) Granting this increase of machinery, it would not, by any means, account for the difference in the power. There was another beam engine in Bolton of a very similar type and size, and which at one time were rivals. This latter engine was running yet, and, he believed, was at this present time producing yarn, per 1,000 weight, cheaper than this new high speed engine. The mill-owner was not only concerned in the quantity of water and coal per IHP, but still more so in the cost of the production of the 1,000 weight of yarn, so that if one engine absorbed more of its own power in driving itself than another of equally economical type, or even of less economy, it might still be the more costly engine to run from the total cost point of view, and he was very distinctly of opinion that the high speed engine when driving a load absorbed a large proportion of its power in overcoming its own friction.

A great point was made of the small wear of the cylinders and hollow piston rods; well, they who were makers of the slow revolution engine, not slow piston speed engine, could show equally good results. The fact was that the wear of vertical cylinders was so very small that it might practically be said to

be nil, but when it came to the wear of the crank shaft, crank pin, etc., the high revolution engine did not show up as well. It had been his privilege to supply several crank shafts for Willans engines to replace broken ones, the old shafts being sent for them to make the new ones to, but when they came to gauge the crank pins and the eccentrics they found them odd sizes (they supposed that they were originally even dimensions), also that the two outer bearings were distinctly less in every case than the body of the shaft. These engines were, he was given to understand, very heavy on crank shafts, and he was credibly informed that the Bolton engine, although only put down in 1892, or about 4½ years ago, was now running with the third crank shaft; whether this was so or not perhaps the author would say.

In all that he had said he would have it very distinctly understood that he had a very high opinion of the Willans engine for what he would term its legitimate use, for direct dynamo driving, but that when it came fairly into competition with slower revolution, double acting, vertical, triple expansion engines of good design, taking into account capital cost and cost of working, in all the points that go to make up the cost, that the makers of the slower running engines had nothing to fear.

Mr. MICHAEL LONGRIDGE said that before he knew the Willans engine he was inclined to regard it with suspicion, if not with dislike, on account of its high speed of revolution, but since he became better acquainted with the excellence of its designs, the perfection of its workmanship, and the small amount of attendance and upkeep it required, he had been completely converted, and would not be disposed to quarrel with the assertion that for small powers or for large powers where the space was too small for long stroke engines it was the best engine in the world. So convinced was he of its excellence that he had even dreamed of

coupling Willans engine directly to the line shafts in a cotton mill, and dispensing with ropes or bevel gear and uprights altogether. A little reflection however had shown that this would be impracticable. Indeed he had come to the conclusion that if the Willans engine was to be adopted for driving cotton mills it must be applied under very much the same conditions as the ordinary long stroke mill engine, and if it were to be so applied it must show some advantage in first cost, in economy of steam, in cost of upkeep. As regards first cost, he did not think there was much to be gained. He had recently obtained tenders for driving a mill where the conditions seemed favorable to the use of several engines of small power, where the adoption of a single engine would have involved the use of a great deal of heavy shafting at all sorts of angles, and yet the cost of the smaller engines was quite as great as that of the larger, with most the transmissions included. Next, as regards economy of steam and power, the results of the experiments given were very good, but no better than those obtained from ordinary mill engines, and he was sorry to say the steam consumption of the Willans mill engines with which he was personally acquainted was not as low as he or the makers expected; it was however only fair to say that in both cases there were unfavourable circumstances. Still he did not think it was possible that a six or nine of small cylinders, especially single acting cylinders, could show as low a steam consumption as two or three of larger diameter with admission to each end.

The great source of loss in a steam engine was cylinder condensation, especially initial condensation. This was, in all probability, proportional to the extent of the clearance surface. Let them compare the surfaces in two engines with 20in. cylinders running with a piston speed of, say, 600ft. per minute, one double acting, with a stroke of 4ft., running consequently at 75 revolutions per minute, and the other with a stroke of

1ft., running 300 revolutions per minute, which would represent the Willans engine. In the first case, the clearance surface might be reduced to something less than 1 square foot per cubic foot of piston displacement. In the second case, owing to the shorter stroke and single action, the same extent of clearance surface would amount to 8 square feet per cubic foot of piston displacement, and the condensation would be eight times as great in the short stroke as in the long stroke engine.

On the other hand, the champion of the short stroke would urge that the more rapid reciprocation would compensate for the increased surface by giving less time for the metal to act upon the steam. No one knew, as yet, how cylinder condensation varied with time of revolution. It was generally assumed that initial condensation varied as the square root of the periodic time. If that assumption were true the higher speed of the short stroke engine would not counterbalance the effect of the eight-fold increase of clearance surface, for it would only reduce the condensation in the ratio of the square roots of 75 to 300, or of 8·7 to 19. Thus on the whole the condensation in the first case would be proportional to 1×19, and in the second to $8{\cdot}7 \times 8$. And if the short stroke engine, instead of having only one cylinder, as supposed, had two or three, the excess of condensation would be greater still. The actual condensation would not be proportional to their figures, as condensation occurred not only on the clearance surface but during the whole period of admission, and where the cut off occurred late in the stroke the difference in the surfaces would not be so great as stated above, nevertheless the reasoning went to show that it was very improbable that the short stroke engine could be as economical in steam as the long.

The next question was, did it absorb less power in itself. On that point he might say that the figures he had obtained from mill engines showed that they required from 1¾ to 3lbs.

referred to the low pressure cylinder to drive themselves. He had only been able to get diagrams from one Willans' engine so far, and in that case the pressure required was greater than either of the figures he had mentioned.

He did not think it possible for small single acting engines to give as high a mechanical efficiency as large double acting.

The last ground on which the Willans' engine might claim consideration for mill driving was the small amount of attendance and upkeep it required, and here he thought the makers had good grounds for blowing their own trumpet. It was on this ground alone that he was disposed to put the Willans engine into competition with the Lancashire mill engine, and it was on this ground principally that he advised its adoption for small powers and for places where little attention was likely to be given to an engine, though of course, its economy, as compared with other small engines, was also a consideration.

Mr. J. F. L. Crosland said that in 1860 his father and himself had patents for driving line shaft of mills without the intervention of gear direct by condensing and by compound condensing engines. Their idea was to largely reduce the weight of engines and to get rid of spur gear, and to run the engines at the then speed of line shaft of mills, namely from 90 to 120 revolutions per minute, and he had made very strong endeavours to get their designs adopted, but the feeling at that time was against rapid reciprocation and high piston speed. His idea had been that rapid reciprocation was the proper thing, and his plan was to have an engine placed in the centre of a mill, and to take power off from both sides of the engine. The engine would, of course, be of light construction owing to its rapid reciprocation and high speed, and also the high pressure at which it should have worked, namely, about 150lbs. per square inch. That was the plan he advocated in those days.

He was, consequently, very favourably impressed by the Willans engine when it was first brought before his notice, as it was one of the most exquisitely designed engines he knew of, and undoubtedly one of the very best of its type.

He desired to draw attention to the figures of the Belfast test, which he thought showed their own inaccuracy. The amount of water evaporated from and at 212° was given at 12·83lbs. per lb. of coal, which had a calorimetric value of 13,200. The efficiency therefore must have been 94 per cent. He would only say that he had never obtained any such result in any tests that he had made. In the test made by himself at Bolton, and referred to by the author, the boiler was 8ft. 0in. diameter with 8ft. 3in. furnaces, as compared with that of the boiler at Belfast, which was 28ft. 0in. in length by 7ft. 6in. diameter. The Bolton boiler was provided with an economiser, and with coal of a calorimetric value of 14,900 thermal units only evaporated 8·06lbs. of water per lb. of coal, or gave little more than 60 per cent. of efficiency. In the Belfast trial he thought some mistake had been made, as the coal consumption was given as 1·185lbs. per indicated horse power per hour. He had made a great number of tests of triple expansion engines but never got any result so low as that, even under the best possible conditions, and he thought that if another test were made in the manner usually adopted by scientific experts the result would not be nearly so satisfactory. In the test he had made at Bolton the steam weight came out at 17·6lbs. per indicated horse per hour. Under the circumstances therefore he thought it would be better if Mr. Robinson would have another trial of the Belfast engine made by some absolutely disinterested person, as some strange mistake had evidently been made. Notwithstanding his predisposition towards engines of this class, he had not been satisfied by anything that had been put before them that the rapid reciprocation

engine was equal, so far as regards economy, to the long stroke slowly reciprocating engine. The Willans engine was no doubt a very excellent engine for those cases for which it was suitable, but he had found that the first cost of a number of these engines for sectional driving, of say, a paper mill installation, was considerably greater than that of a single engine, and that taking all things into consideration, the first cost, attention and cost of fuel, it appeared, at any rate so far as his experience had at present gone, that the advantage rested with the ordinary Lancashire triple expansion engine. In considering a matter of this kind, although no doubt Mr. Robinson had made out an extremely good case for the Willans engine, and that it was undoubtedly a highly satisfactory motor, yet there did not appear to be any reason why we should reject the ordinary long stroke Lancashire engine for mill purposes in its favour.

Mr. INGHAM said that from his experience the taking of diagrams from a Willans engine was sometimes difficult, and it might be that the Belfast figures were quite correct and yet the results be entirely misleading. He had recently taken some diagrams of a Willans engine and was considerably puzzled with the result. One of these engines was running at 582 revolutions per minute. Now, in indicating the ordinary reciprocating engine they got the motion for the indicator from the piston rod, or some moving part whose motion was exactly coincident with the motion of the piston, so that every point in the diagram coincided with the piston stroke. In the Willans engine the motion for the indicator was obtained from a separate eccentric, and it was possible that if this eccentric were not very carefully fixed and adjusted so as to show the pressure on the diagram at every point of the stroke coincident with that of the piston, there might be room for considerable error. If, for instance, the cut off was shown rather later in

the diagram than it actually took place in the engine they would probably get a greater area of diagram than they ought to do, and consequently a greater IHP. The engine referred to although prepared for condensing was really working non-condensing, and he could vouch for the accuracy of the weights of coal and measurements of water. The result in dry steam per IHP was 22lbs., but there appeared to be some leakage in one of the buffer cylinders. The ordinary diagrams, he supposed, from a buffer cylinder usually showed very little power absorbed. In one of these he got no less than 14·8 IHP out of a total of 78 IHP, which was a very large percentage. If they took this as lost power they found a very high efficiency, much higher than could be expected; if it was not deducted the efficiency was exceedingly low, and there appeared to be a possibility that the eccentric which actuated the indicator did not give a motion coincident with that of the piston.

They must all be obliged to the author for the trouble he had taken. No doubt in Lancashire a good deal of prejudice existed against the Willans engine. It was, however, a marvel of ingenuity; the prejudice against it was rapidly disappearing, and they would all watch with the greatest interest any further development for making the engine suitable for mill work in this district.

Mr. A. G. Brown said that, from a large experience, he knew something of the capabilities of high speed engines. He did not think they would be used as large mill engines, but there was a possibility that they might displace the large mill engine by a series of small ones with economical results. Mr. Crosland had spoken of researches into the subject with a view of utilising them in paper mills. Well, large engines had been displaced in paper mills, and small ones put in for driving independent machines, and there had been a saving in the amount of coal used. The theory that a large engine would

drive a whole mill and that because some machines would not be working all the time they would mutually balance each other so that a steady load would be obtained, was found in paper mill practice to be not quite correct, and in consequence of that the fact that they could use the machines when they wanted and shut them off when they did not, and still keep the engines at the most economical point all the time, had resulted in a great saving. That was not quite so possible in cotton spinning mills as in some other mills, because the loads were more evenly balanced, and they got very little change during the day, and therefore the engine which was designed as a large engine to run them, would run at its most economical point all the time. There was, however, sometimes an advantage in dividing a mill up into sections and being able to stop one part or another as desired, and that was the only direction in which a high speed engine would come in for cotton mill work. As to the amount of wear he could fully bear out Mr. Robinson's statements. They had run an engine 11 months, without a stop, at 310 revolutions per minute, and on being taken to pieces there was nothing to do with it. Another was run 23 months without steam being taken off, and in that case new brasses were put in and the old ones laid by, as repair-parts to be used again, if necessary. There were numerous other similar cases which he knew of.

One thing in which they prided themselves as engineers with regard to economy was the effect of a governor cut-off applied to an engine to regulate the speed. This could not be applied to a Willans engine, and, therefore, perhaps the small port clearance was not so great a gain, as it was balanced by the loss of the above point. In his experience he had never been able to get as good results with a throttling engine as with an engine having a governor cut off. The latter gave the best results, although this point could be got over, to some extent, by super-heating,

which had an important bearing, especially upon high speed engines.

Mr. R. GREGORY said if mills were to be driven independently in separate sections, it would have to be done electrically and not by small engines, spread all over the mills, as in case of a lot of small engines there would be a perfect net work of steam pipes, which would be a great loss through condensation alone. He knew of a place in Scotland where they drove by motors, on account of being three small mills, none of which were in line with each other. This dispensed with a large amount of gearing and worked perfectly satisfactorily, with a great reduction of power.

With regard to the Belfast figures, he had never known a case of 11lbs. of water being evaporated per lb. of coal, where the coal had only 13,200 thermal units of heat in it. Then again, the test was only of one day's duration, whereas it ought to have extended from two to three days, so that any variation or errors might have been ascertained.

Mr. DANIEL ADAMSON (visitor) said that owing to the lateness of the hour he would be very brief. His firm, Joseph Adamson and Co., of Hyde, have had some experience during the last few years on this subject of high speed engines, and they were at first in the condition of mind mentioned by the author, that is to say they were very doubtful as to the advisability of putting such an engine down when it would practically have to take care of itself. Being, however, persuaded to make what was to themselves at any rate an experiment, the result had quite justified the step as far as they had gone yet, although they could not claim any lengthy experience. Their first high speed engine, 50HP., running at 500 revolutions, was started in November, 1894, and ran without much attention to bearings, &c., until early this year, making about 5,900 hours or say

17 million revolutions when they had it thoroughly overhauled and considered it a better engine to-day than when it started; and this, although it was a *double acting type*, and not one of the single acting ones eulogised by the author, worked under very different conditions from the mill engines mentioned in the paper; the load often varied instantaneously from nothing to about 30 % overload as would be readily believed by anyone with experience of electric driving by means of individual motors which stop and start and reverse as required by the machines or cranes they may be coupled to. One or two points he would like to ask the author for some definite information on, and he mentioned them rather to give the author an opportunity of refuting them than because he believed they had much foundation in fact. It had always been his impression, gathered by conversations with persons whom he believed to be disinterested, that the Willans engine was so very complicated that only highly experienced men can undertake its adjustment, and that, therefore, it was essential to have this experience within easy call. Another point was, and he wished to impress upon all that these were only rumours which he now put into a proper form for annihilation, was that the Willans engine, being so nicely proportioned for its work in every part, with the object of saving weight, any hitch or accident was very liable to cause a serious breakdown. Of course they might say that the engine could be held responsible for accidents outside itself, and it was to these the speaker referred in particular; but accidents did happen and it was advisable to minimise their consequence as much as possible. It was in this connection he appreciated the advantage of having everything to gauge and templet so that it could be replaced by the makers immediately from stock with the certainty that it would fit its place. It was unfortunate that the only figures as to economy given by the author were now over two years old, and, moreover, on looking into the figures

undernoted for the performance of the boiler, the speaker found the results obtained were remarkably good; so good in fact, that he asked the author to look through again before actually publishing them. If a novice might be allowed to return to a matter that had already been referred to by such an authority on tests as Mr. Crosland, the speaker would like to give a few simple calculations he had made. Taking the figures given, the pounds of water evaporated from and at 212° were given as 12·83, which, multiplied by 966, gave 12,400 thermal units of heat transmitted from the coal to the water in the boiler. Now, on page 153, the number of thermal units in the fuel used was given as 13,200, which gave percentage efficiency to the boiler and economiser of 94%, which was, of course, impossible, as it left only 6% for radiation losses, for the loss of heat in the waste gases passing through the chimney, and from the loss of heat with ashes, &c., withdrawn from the ashpit.

For the waste gases alone it was probable that the loss of heat amounted to, at least, 9% or 10%, which would be a remarkably good result in itself.

Assuming, for instance, that the temperature of the air in the boiler room was 70° and the temperature of the waste gases as low as say 370°, giving a net rise of temperature of 300° F. to each pound of waste gases passing away; assume also that the weight of waste gases passing away equalled 18lbs. per lb. of coal, which would assume good conditions of combustion, and taking the specific heat of the waste gases at roughly ·24, this would give $·24 \times 300 \times 18 = 1296$ B.T.U. per lb. of coal equals 9·8% of the total heat of the fuel lost in the flue gases.

The speaker said he left the figures referring to performance of engine to others more capable of dealing with same, and in conclusion thanked them for the opportunity given to him, an outsider, of joining in their discussion.

Mr. E. G. CONSTANTINE observed that no reference had been made to the increasing practice in Lancashire of direct-driving by means of vertical engines. No one could question the fact that the chief point of any high speed engine lay in its being a vertical design. He was pleased to see that there was a tendency amongst Lancashire engineers to adopt that design for either direct-driving or belt-driving double acting engines. The first advantage claimed on page 135 was largely met by the vertical engine, and it was undoubtedly going to play an important part in mill driving in the future. He was, however, referring to the double-acting engine, which possessed advantages over the single-acting engines, and supplied practically the speed required in Lancashire for the first or second motion shaft, *i.e.*, up to say 200 revs. per minute. There was no difficulty in getting that with a well balanced double acting direct engine. This was fully confirmed by marine practice. Take, for instance, cruisers at from 130 to 170 revs., with engines developing up to 10,000 HP, it would be found that even for high speeds double-acting engines were perfectly suitable.

One difficulty of very high speeds in cotton mills was the transmission through ropes or gearing, which would necessitate a clumsy arrangement of pulleys for reducing the speed from the engines to the shafts.

Undoubtedly high speed single-acting engines, as described by the author, possessed superior advantages over double-acting slower speed types for the purposes with which they were at present identified, but he failed to see that anything would be gained, either in economy in first cost, working or maintenance, by adopting them for mill driving in place of well designed double-acting (preferably vertical) engines. He greatly admired the Willans engine, which was a marvel of perfection in

workmanship, and he wished his thanks to be added to those of the other members, to Mr. Robinson, for his paper.

The PRESIDENT (Mr. J. Nasmith) said there was a wide difference between putting in a high speed engine to drive a dynamo and putting one down to drive shafts which had to transmit motion to cotton mill machinery. In the first place, the speeds of the various machines in a cotton mill were widely different, involving sometimes different speeds of line shafts, and in consequence necessitating the use of some means whereby the speed could be differentiated. Taking carding engines for instance, the cylinders of which had to be driven, at the outside, a couple of hundred revolutions per minute, and mules, where the driving pulley had often to be driven at 700 or 800 revolutions, both, in some instances, directly from the line shaft, they must provide some appliance for getting the speed up from the different machines. Some division of the power was essential, as there were many rooms to drive.

As to quick running shafting, this was an American idea, and had been carried out in that country to a somewhat ridiculous extent. Very light shafts were used, with the effect that bearings had to be placed at short intervals to sustain the stress on the shaft caused by the pull of the belts, so that what was gained in speed was more than lost by the friction set up in the bearings. Experience had shown that too great a speed of shafting was a mistake, and practice now ranged from 180 to 200 revolutions for line shaft.

As Mr. Constantine had said, it was not good practice to start with a high speed and reduce it by large pulleys at the ends of the shafts, which should not be larger than was necessary to transmit the power for each room.

Another difference between driving dynamos and cotton mill shafting directly was that the dynamo provided its own fly

wheel, which was found in the armature, whereas in a cotton mill there had to be a separate fly wheel in order to get that steady running which was so much desirable, and to transmit the power to the various rooms.

High speed engines ran well and steadily for electric driving, but they also got steady driving, few repairs, &c., in what were called the slow running mill engines, and these latter would, for their purpose, prove more economical in steam, require no more repairs, and afford as steady driving as the high speed engines. The engines of the Mutual Mill, at Heywood, had engines with a steam consumption of 12·2lbs., which could be readily vouched for, and high speed engines would have to be well designed to beat that.

With regard to "constant thrust" which, the author stated, ensured a more constant stress on the crank and crank pins, and prevented the "friendly lift" which let the oil in, no doubt this was quite true. The steam, of course, was on the top of the piston, and while the work was being done the thrust was downwards and the power was then being exerted, but when the piston was coming up and there was no work being done except the compression in the cushioning cylinder, there must be a wide difference in the amount of the stress that existed in the two periods; this power could only be settled by a plotted diagram of crank pin stresses, or better, a diagram of the stresses on the crank shaft. They would get what was equivalent to the pull, as contrasted with the push, because there would be a slight relief given to the crank pin as it was coming up with the lighter load, which would in some sense be equivalent to the stress put on by what Mr. Robinson very aptly called the "pull" of the engine.

Further, the work which is being done during the upward stroke of the engine in forming the cushion was equivalent to offering a resistance to the rotation of the shaft. In an ordinary

reciprocating engine the effect of the "push and pull" is to give a series of impulses always in the same direction to the crank shaft, whereas in an engine of the Willans type fitted with the cushioning arrangement, there was one period during which the crankshaft received an impulse, and another during which it was being checked or resisted by the work of lifting the parts and forming the cushion. This appeared to him to be a matter of some gravity, which would however be more noticeable in single or double cranked engines than in those having three cranks.

There was one question he would like to refer to. Mr. Constantine had mentioned the inverted vertical marine engine as a type to be adopted. While agreeing that that class of engine had many merits, there was one point in which he thought it failed. The centre of gravity was ordinarily so high that at any very high speed vibration was almost inevitable. In that respect the Willans engine set a good example, as the weight was so distributed as to bring the centre of gravity much lower, with results which were apparent in work.

Having said so much it must be freely acknowledged that the Willans engine had done much to enlighten engineers as to the proper use of steam, all the information gained having been freely thrown open to the whole engineering profession. If engineers generally would see to it that they made all their engines as well as the Willans engine it would be a good thing, and it had already exerted a great influence in this direction. The classification and the systematic methods adopted were worthy of the highest possible praise.

He had pleasure in moving a vote of thanks to Mr. Robinson for his paper.

Mr. Webb seconded the motion, which was unanimously adopted.

Mr. A. Rea (in a communication) in referring to the matter, regretted that the exigencies of the occasion prevented a fuller discussion of this very important paper. But he must confess that the several speakers somewhat missed the point at issue, which was tersely put by the Chairman, namely, the suitability, or otherwise, of high speed engines for mill driving, and of the Willans type in particular, it being fully admitted by the most eminent authorities that for direct driving and electrolytic work the Willan's engines, in economy of steam and smooth running, had no equals, arising from the principle of construction, which is altogether different from the usual practice in general engineering design.

The author therefore based his case very clearly, viz., that if said engines were pre-eminently suitable for direct driving, their success being undoubted, it rested more particularly with their opponents to prove the converse, when applied to textile machinery.

The advantages therefore, as briefly stated in the paper, resolved themselves into reasonable problems for discussion. The question however naturally arose, "What are the drawbacks or disadvantages which would militate against the use of said engines for mill driving?"

Where economy of all kinds was a desideratum, and where uniformity of turning is a *sine qua non*.

In addition to the general high speeds required for the different lines of shafting, which might be taken as varying from 150 to 300 revolutions per minute.

From the simple statement of facts as given, by the author, all deduced from actual experience, it would be clearly seen that the drawbacks, like the ghosts of fable, which seem formidable at a distance, vanished when they came near. At the same time there were one or two points which required a little more elucidation.

First, taking for granted that said engines were considerably lighter in construction, per indicated HP, than its slower working competitors. Did the writer claim a corresponding reduction of friction in turning, or merely the loss arising from the use of rope, belt, or other gears, in getting up the speed, as the former could not be very well sustained. The kinetic theory being that it required a unit of force, acting upon a unit of mass, for a unit of time, to produce a unit of velocity. Therefore the lighter engines, at the greater number of rotations, would fully absorb as much power as the slower and heavier machine.

Second, as to the question of radiation and condensation, the writer understood that it had been found from actual experiment, owing to the special construction of said engines, with a central valve, and the short duration of steaming, etc., on each cylinder, that practically the walls of the cylinders were not heated over ¼in. deep, and that the truncated bottom in the receiver, made for evaporative purposes, became almost inoperative, condensation being *non est.*

Third, it was to be regretted that no special reference had been made to one of the distinctive features of these engines, viz., the straight line principle. It being a well known statical law that everything moves or flows easiest in the direction of least resistance, which is a straight line. It was evident, therefore, that considerable advantage must follow from this principle, being fully carried out in said engines more particularly than in any other.

At all events he had listened to, and also read, the paper with great interest. The case had been fairly stated, and would require considerable refuting before being upset, as no valid objection can be raised thereupon. At the same time it was just possible that the general verdict for the present would be that a great deal could be said upon both sides. Personally, he had pleasure in thanking the author for his most excellent

paper and the great trouble he had taken in relation thereto, which had made all indebted to him.

Mr. MARK ROBINSON, in reply, thanked the meeting for the not only generous but cordial reception which had been accorded to the paper, and, above all, for the very practical discussion it had called forth. Generally, the opinions expressed with regard to the high-speed engine, and to the Willans engine in particular, had surprised him by the warmth of the appreciation shown: it was evident that the high-speed question had advanced further in the North than he had supposed. He had devoted his paper mainly to the defence of the high-speed engine against certain assumed objections, but he was agreeably surprised to find that his case was, by so many of the speakers, accepted as largely made out. Their objections mainly took the form of a denial that the high-speed engine was any better in regard to economy, first cost, or durability, than the best existing Lancashire types. Far be it from him to claim for it such a position. His only aim was to show that in these respects it was as good as slow-running engines, leaving its admitted superiority in other directions—smallness, lightness, absence of trouble and convenience generally, to secure for it, in the end, a fair share of the approval of users.

With regard to economy there was, perhaps naturally, a tendency to view the claims of the engine as based upon the Belfast trial, particulars of which were given in the appendix to the paper, and one speaker had urged that the engine should be re-tried by an independent authority. But, as a fact, Mr. Wilson was absolutely independent. Mr. Wilson was wholly unknown to him and to his colleagues when he first advised Messrs. Gunning and Campbell to put down a high-speed engine for their mill, and he stood in no relation to the engine and its makers other than that of a consulting engineer,

courteous and considerate, certainly, but as determined to exact the last shilling which he considered due to his clients as any consulting engineer could be. It was because Mr. Wilson was so absolutely independent of himself that he had sought permission to add Mr. Wilson's report to his paper. If there was another reason it was, of course, that trials of high-speed engines on so large a scale, and made with such evident elaboration and care, were by no means common.

It had been contended that the figures for evaporation gave an impossibly high result for the reported calorific value of the fuel, and so discredited the whole trial. On this he would remark first, that, as stated in a foot-note, the determination of the calorific value of the coal was not made by Mr. Wilson, but by an outside authority, and that the figures might not have been reproduced properly; secondly, had the full effect been considered of the waste gases from the *second boiler*, which passed through the economiser, and which not only thus contributed many heat units to the work of evaporation, but also assisted to keep the adjoining test-boiler warm, and further, made a chimney draught for it, enabling the test-boiler to be run with the damper partially closed. All these points combined made a phenomenal result not unnatural.

He had seen reports of trials by authorities of the very highest eminence, in which the evaporation fell little if at all below the figures given by Mr. Wilson, though no doubt, in these cases the calorific value of the fuel was reported to be greater. He must confess, however, that in asking permission to publish the report he had not thought of looking at the figures relating to the boiler; they were merely published because they belonged to the trial. It had been one of the strong points in the position of the late Mr. Willans that he had refused to test his engines by anything but

steam consumption. If the mind is taken off that simple but very difficult issue, and is allowed to rest upon the easier but less instructive issue of coal consumption, then the most hopeful road to progress in steam engine economy commences to close against us. Only when the engine test is separate from the boiler test (as it was at Belfast, though both were tested) is the great problem likely to be advanced. Whatever might be said about the boiler figures, however, there was ample corroboration for the engine figures.*

They had never on the steaming beds at Thames Ditton, attained to quite such low figures as 12·49lbs. per IHP, because in the first place, they had no means there of testing such large engines (at Rugby they hoped to be able to test up to 1,000 IHP), and in the second place the engines tested there were invariably new, with none of the internal working surfaces brought to the polished state which a few weeks of running would ensure. Nevertheless, they frequently logged 13lbs., with triple-expansion and high-pressure, measured by testing appliances of an accuracy and perfection very difficult to rival in trials conducted in an ordinary engine-room. These repeated results, often obtained under guarantee, and in the presence of critical engineers and customers, must be his answer to all those who based their objections either upon presumed doubtfulness in the Belfast trial, or upon mere

* In the *Textile Manufacturer* for 15th October, 1897, is an account, stated to be derived from *La Revue Technique*, of an economy trial of a triple-expansion Willans engine of 700 I.H.P., laid down to drive the cotton mill of the Societé des Filatures de Laval, in France. Nothing like full load could be put on, and the engine seems to have been tested under conditions very little favourable to economy, and still less to good mechanical efficiency. The steam consumption is given as :—

With 885 I.H.P. — 13·49lbs. per I.H.P.-hour.
„ 399 „ — 13·24lbs. „ „

and the mechanical efficiency at this low load is stated to have been "a little higher than 86%, *including the power absorbed by the air and feed-water pumps.*" The latter were driven by an independent motor, and it was stipulated that the power consumed in driving them should be treated as friction loss in the engine The trials were carried out in March, 1897, by the Association des Proprietaires L'Appareils à Vapeur de l'Ouest, "after a continuous working of seven or eight months." The builders, Messrs. Willans & Robinson, Limited, had no part in the trials.

à priori reasoning. Indeed, some speakers seemed to have no other objection to offer to the claims of the Willans engine than that such results did not seem "possible." But that was just the point which trials and tests were competent to settle, and he claimed that they had settled it.

He was informed that at about the same time as the trial of Messrs. Gunning & Campbell's engine, Mr. Wilson conducted an economy trial of a much larger triple-expansion vertical engine, driving another mill in the same district, and which also had been newly put down upon his advice. This engine was by one of the most eminent makers in Lancashire, or in the world, and its consumption, under practically like conditions, was precisely the same as in the Willans engine. There was a small decimal in favour of the latter, but for practical purposes the figures were identical. That was simply the position he took up upon the question of economy—that the high-speed engine, in the particular form of the Willans engine, used as little steam as the very best engines in existence, while in most points of practical convenience it surpassed them.

Mr. Michael Longridge doubted this, and so did Mr. Crosland, but he ventured to submit that the weight of evidence was against them, and would ultimately compel their adhesion. Meanwhile, he could but thank these gentlemen for the extremely kind way in which they had referred to the engine.

Another view which had been discussed in a very interesting manner by Mr. Longridge, Mr. Crosland, Mr. A. G. Brown, and Mr. Gregory, was that of driving mills in sections, by means of a number of small engines. There might be cases where this plan would be advantageous, but for the ordinary cotton mill he did not advocate it. The proposal did not really help his argument, because his contention was that, as a *large* engine, and not merely as a small one, the high-speed engine could meet the largest and best of its opponents upon absolutely equal

terms as to economy, and beat them upon every other point. Mr. Gregory had referred to the losses from the network of steam-pipes which a number of small engines would require. He doubted whether these losses would not, in ordinary cases, be worse than the losses in transmission by belts or gear.

Mr. Saxon, Mr. Hartley, Mr. Hodgson, and he thought, other speakers, referred to the comparatively low piston speed of the Willans engine, as though it in some way derogated from the claim that high economy was in part the result of "high speed." But he would venture to say that high piston speed, though it might cause inconvenience through the inertia of the fast-moving parts, could in itself do nothing to aid economy, save as an index to high rotative speed. The economy came in through *short exposure of the cooling surfaces*, the shortness of exposure depending of course upon the number of times per second in which the steam was alternately admitted and exhausted. If the time of exposure of the cylinder surface to exhaust steam was *long* the walls would be much cooled, and as the succeeding exposure to live steam must be correspondingly long much of the live steam would be condensed: first, because it was exposed longer; secondly, because the cooling surface had been cooled to a greater depth. If during the time of exposure the piston made a long stroke, that really afforded no compensation; if the time were the same and the surface the same the quantity of steam condensed must be the same.

Mr. Longridge had dealt with this question of condensation. He had such unrivalled stores of *data* about engines of all types that the speaker would not venture to contest his view as to the relative *amounts* of cooling surface exposed in fast and slow-running engines. But as to the limitation on condensation, imported by high rotative speed, it appeared to him that its law was at present unknown. Practice, however, said plainly that there was *less* condensation in small fast-running engines than

in large slow ones. Every chance which offered for collecting information on the point seemed to confirm this view. At any rate it was certain that the high-speed engine soon reached a speed at which jacketting ceased to have any value in diminishing condensation, and as this was apparently not the case with slow-running engines, it must surely be conceded that, from the point of view of initial condensation, the slow-running engine, even with the best of jacketting, could barely attain to the immunity from initial condensation which the high-speed engine possessed, so to say, automatically.

Some speakers had impugned the mechanical efficiency of the high-speed engine. But this was a point, owing to the hundreds of accurate tests which had been made of dynamo-driving plant, upon which the makers could speak with unusual confidence, and he could assure Mr. Hodgson that, in the few cases where they could get *data* about the mechanical efficiency of engines of the mill type (as when employed to drive dynamos) they did not show to advantage against high-speed engines. He confessed that no other result would appear probable to him. Mr. Longridge said that mill engines could be run light with from 1¾lbs. to 3lbs. mean pressure, referred to the L.P. pistons. Undoubtedly a Willans engine needed more pressure than this, and this would be natural, because the friction of the Willans engine was almost wholly ring friction, which of course remained constant at all loads; the bearing friction in these engines, for reasons well known to them, was equally negligable at all loads. An engine whose friction was mainly in bearings or in slide-valves would, of course, show but little friction when unloaded: the question was, what would it show when fully loaded, if it were possible to put it on a brake? The Willans engine, when tried light, revealed the whole extent of its friction loss; innumerable trials showed that it would never lose appreciably more, however great the load or over-load

might be. But the mill engine, unloaded, told you nothing of what its losses were going to be at full load; all you knew was that they were going to be a great deal heavier. Still another point remained in connection with this friction question. In the engines which Mr. Longridge compared, were the ratios of expansion similar? May it not have been the case that the mill engines had much greater cylinder area (and volume) than the Willans engines compared with them. If so, 8lbs. mean pressure in the one case might imply as great a proportion of power as 4lbs. or 5lbs. in the other.

Mr. Hodgson adverted to broken crank-shafts of Willans' engines, which he had had to replace. Possibly he referred to the well-known case of the Manchester Square engines. It would be difficult to deal with that case without taking up too much of their time, but he could make Mr. Hodgson a present of the misbehaviour of those shafts without in the smallest degree abating the extremest claim he had made to phenomenal durability in the Willans engine, and in all its parts. One of the Bolton engines, as Mr. Hodgson said, was running with its third shaft. The first had broken from a flaw, but it was fair to say that its design, as regarded dimensions, was an early one, and that it was below the standard in use for some years past. Two forgings were then obtained, of course in haste. One when nearly finished developed a huge central flaw; the other which appeared sound was then finished, but it was afterwards found that it was defective in the same way and it had to be replaced. There was nothing in these facts which told against the principle of high speed, or of constant thrust, and they were of no importance in the face of overwhelming evidence on the other side.

Mr. Ingham's experience in indicating a Willans engine, apparently a very small one, certainly showed something wrong, but whether it was in the engine or in the indicator it would be

hard to say. The speed named—532 revolutions—probably made reliable results very difficult to obtain. At Messrs. Willans and Robinson's works they rarely attempted to indicate at over 400 to 450 revolutions, but up to those speeds they had no serious difficulty.

Mr. Brown was in error in supposing that automatic governing could not be applied to the Willans engine. The Belfast engine, so often referred to, had automatic governing.

Mr. Adamson's experience with double-acting high-speed engines only added force to the arguments in favour of high-speed as such, and Mr. Constantine's remarks tended in the same direction. Mr. Adamson asked if the Willans engine was not very complicated, and if it was not given to breaking down. The speaker ventured to think not, emphatically, but he felt that he was hardly the proper authority to which to refer these delicate questions.

The President's remarks went very straight to the point, and he could assure him that high speed engine advocates had no wish to interfere with established doctrines as to speeds of mill-shafting and the like. They felt it was quite enough to have one novelty on hand at a time. He must demur a little to the view that in electric lighting the armature served as a fly-wheel. In the great majority of cases the armature was a mere drum of small diameter, and even when the weight and diameter were considerable the structure was often too weak to allow of its use as a fly-wheel. As a fact the fly-wheel conditions affecting high-speed engines were generally the same as for low-speed engines, where irregular loads had to be provided against. The President's remarks as to the *retarding* effect of the cushion cylinder upon the up-stroke doubtless had reference to steadiness of running. But it must be remembered that the cushion pressure was designed, as far as practicable, merely to *equal* the inertia of the parts upon the up-stroke, with just so much

margin as should ensure holding them down. The "retarding" influence was therefore a very small one, and since practice was always more telling than theory he must ask them to look again at the diagram on Page 149, and say if any engine, with air-cushioning or without, had ever produced a straighter speed-variation record than that.

The President's concluding remarks were most kind. As Mr. Rea wrote, there was no doubt a good deal to be said on both sides. The pleasant thing about this discussion, to him, was that the "other" side had been so vigorously represented, and yet had shown so broad-minded an appreciation of his side of the question. He thanked them all most sincerely.

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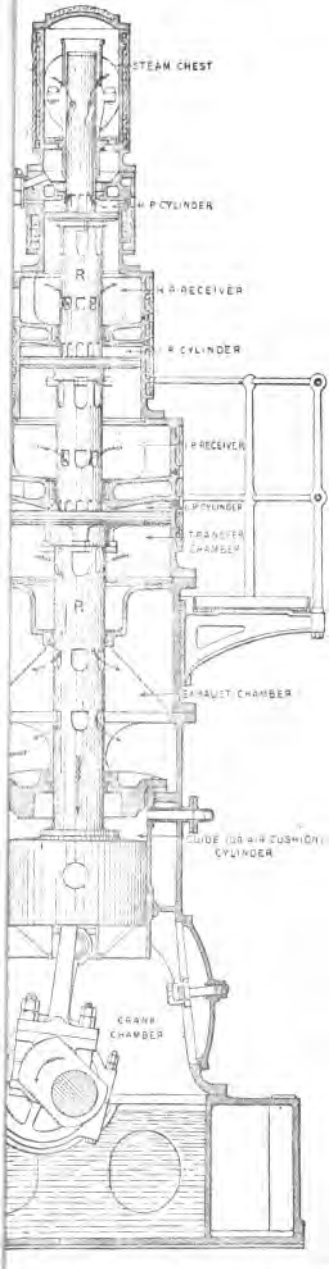
1 Plate follows illustrating this Paper.

Plate 1.

INES FOR MILL DRIVING.



E EXPANSION CENTRAL VALVE ENGINE.
TO INDICATE 500 H.P.

UNIV
OF
MICH.

Opening Meeting

OF THE

42nd Discussion Session.

PATENTS AND PATENT LAW.

The 42nd Discussion Session was opened on Saturday, the 9th October, at the Grand Hotel, upwards of 70 Members being present.

Tea was served to the Members at six p.m., the Chair being occupied by the President, Mr. Joseph Nasmith. A short interval followed the conclusion of the tea, after which the President again took the chair and delivered, as indicated in the syllabus, a short address on Patents and Patent Law.

The President said:—It is admitted that the patent laws of this country are in some respects in a very peculiar condition, and I will point out to you some difficulties in connection with them which are of prime importance. I am not going to look at the question from the point of view of the lawyer, but of the inventor. There is a good deal of misapprehension as to the question, "What is patentable?" As time goes on every part of a machine speedily becomes covered by a large number of patents, and of course a difficulty arises in devising something fresh without treading upon the heels of some previous inventor.

Now, to begin with, no principle can be patented. You could not for instance patent the principle of the expansion of steam, supposing you were the first person to find it out, unless you showed some special means by which you could carry the principle into effect; but you can patent—and this is rather paradoxical—a process, provided the process consists of a new method of attaining an old end. Well, you

say, "That is a principle,"—but it is not. It is an *applied* principle; it is the carrying of a principle into effect by some means which you yourself have devised. For instance, when the hot blast for smelting pig iron was brought out, it was held that the inventor of the process, although he had done nothing more than heat the air, which was blown into the furnace, had in addition to that shown the method by which the air could be heated, and by showing the method he had practically secured the principle as long as his patent lasted. If, however, he had merely said that from the use of air heated, certain advantages will follow, and had not shown any method by which the air could be heated and utilised, his patent would have been invalid.

That of course goes rather farther than the great bulk of the patents with which we have to deal. These consist mainly in combinations of elements or of mechanism. Combination of elements are more often heard of in connection with chemical patents, and with regard to these the Courts have always drawn the line very closely. You can easily understand the reason for this. A chemical patent must be for some reaction which takes place within certain specified limits, and the introduction of two or three more atoms of oxygen or hydrogen or nitrogen may make all the difference in the result obtained, so that it is not only desirable, but necessary that chemical patents should be considered very closely, because otherwise you would have a man claiming practically the whole of the combinations of a series, and preventing other people from doing the same thing.

When we come to combinations of mechanism, however, it is obvious that there is a very wide range; you can take a large number of parts, and, so to speak, "ring the changes" upon them. It is a question of permutations, and you can make a large number of combinations out of the different parts. The law says, "If you can take any number of the old parts and combine them in a new way, or make a new combination so as

to produce a new result, the invention is patentable." It is very easy to see that if we were to construe our patent law as literally as they do in America, where the inventor has to claim absolutely all the combinations which he wishes to patent, and is confined to those combinations, a good deal of trouble would be removed.

Our judges in dealing with patents law, generally do so from what is called the benevolent point of view. They say, "What does this thing do? What object is attained by this combination? By what equivalent of this combination can you attain the same result?," and they hold that the equivalent is within the combination, so that by this benevolent interpretation of the law you obtain an extension of it, which renders it very difficult to make a fresh combination which shall be really patentable. I think I am well within the mark in saying that there are not 20 % of the whole of the patents which are taken out in this country, and on which taxes are paid, that are worth the paper they are written on, simply because some earlier patent, interpreted in the above liberal way, will be found to include them.

Now, that is a general statement. I pass on to a point that has come to the front very prominently during the last five or six years in the courts. Combination patents are becoming more and more frequent; combinations are consequently becoming more and more narrow, and the difficulty is to find a new combination. Therefore, to establish a patent at all, there must be sufficient invention in it to satisfy the courts that there is really a new combination in it.

The courts have, however, chosen during the last five or six years, and very rightly too, to apply another test as to whether a combination is patentable or not. They have laid it down in more than one case, that the utility of the new combination, as compared with the utility of the combinations previously

existing, forms some measure of the subject matter or of the patentability of any particular combination. What I mean by that is this. Supposing you had got a combination in which there was only a very small amount of invention, but the result accruing from it was a very useful one, from the point of view of the public; then the utility of the combination would carry your small invention over the border line, between subject matter and no subject matter.

Let me give you an instance. It has been held in quite recent years that the substitution of a moving strap for a fixed strap in a certain machine constituted, by reason of its utility, an invention. Now that seems to be a very small thing. You have simply to take a strap which has previously been held, and which has been used for the purpose of communicating a rolling motion to some rollers and make it move, and you obtain subject-matter for a patent. The fact of the matter is that by changing the mere rolling gear into an epicyclic gear, you were able to obtain a greater gradation of regulation and produce effects and do work which you were not previously able to do. The great utility of that small step was sufficient to create and render possible a very large trade, and the utility of the invention was practically the thing which carried that patent through.

It is a very common thing for men to be met, when they come into the patent courts, with the term "prior user" or "prior publication." With prior publication I will not deal, but with "prior user" I will, because it very often happens that when a man is devising a machine he takes it into his workshop, and says to a man employed there, "Take this machine; here is the central idea; work it out." And when the central idea is worked out, and made a success, the inventor takes a patent for the thing. Now that, in the eye of the law, does not constitute such a "prior user" as renders the patent

invalid. The law says that confidential, experimental, or secret usage, for the purpose of perfecting an invention, prior to patenting it, does not invalidate it. In one case a man made a set of paddle wheels, or got another man to make them for him secretly. The paddle wheels were made and exported to another country prior to the taking out of the patent, but that was held to be secret usage and did not invalidate the patent. Messrs. Dollond took out a patent for grinding lenses. It was proved that these lenses had been used in 1790 secretly by another person, but that secret user did not invalidate the patent.

In another case a machine for making cards was actually sent out to another workshop, where it was used publicly for the purpose of trying whether it was successful or not, and that was held not to invalidate the patent. This is, however, a dangerous thing to do, because although it may not invalidate the patent, provided you are the first to obtain it, someone may walk into the shop, see the machine, obtain the idea he has been waiting for a long number of years, and go and patent it, and you will come off second best, unless you can prove to absolute certainty to the courts that this man did derive his invention from you, in which case he is not the true and first inventor. When Saxby and Farmer sued the Gloucester Wagon Co. for infringement of their patent, it was proved that drawings illustrating this patent had been in the L. & N. W. Drawing Office at Crewe; a large number of railway men had seen them; there was no concealment, and that was enough to invalidate the patent. While you are permitted to make experiments, so long as they are confined to your own shop they are pretty safe, but if you make them elsewhere, you run the risk of someone else picking up the idea contained in the invention and running away with it.

I now wish to consider the position of foreign patents in this country. This is a point to which Mr. Levinstein has been calling attention, and which the Manchester Chamber of

Commerce has taken up with a considerable amount of vigour. Of course in the chemical trade we can quite understand that the shoe pinches very considerably. Aniline dyes were the invention of an English chemist, and were perfected to a large extent by English chemists. The Germans took them up, and by reason of the greater number of trained chemists they have in Germany, they have taken practically the whole of the trade, and have a monopoly of it. Naturally the chemists in this country do not see why this should be. The Germans make the dyes in Germany, employ German labour, and flood the English market with German dyes.

The chemical manufacturers here are somewhat aggrieved, and no wonder. In every other country in Europe it is a condition on the granting of a patent to a British or foreign subject that the invention shall be worked within the country, within a specified time, or otherwise it may be declared void.

You can easily see that the English inventor who throws his market open here, by reason of the law, to any inventor from any part of the world, finds himself very often in a difficulty. If he wants to get the benefit of an invention in foreign countries he must go abroad and find someone who will make his machine on terms that will allow him to get something out of it. In many cases the game is not worth the candle; in others, it is. In this country, however, we have chosen—following a policy which is, perhaps, foolishly free—to embody in our law a clause by which compulsory licenses can be granted on certain conditions.

"If on the petition of any person interested it is proved to the Board of Trade that by reason of default of patentee to grant licenses on reasonable terms, the patent is not being worked in the United Kingdom, or the reasonable requirements of the public with respect to the invention cannot be complied with," then the Board of Trade is to have power to grant compulsory licenses.

If you say, "Well, now, we ought to have a compulsory license to make this thing in this country; we are quite prepared to make it on such terms as the Board of Trade likes to fix," you are met with the cry, "The reasonable requirements of the public are satisfied, nobody can say they cannot get as much as they want of it." Therefore, the Board of Trade cannot do anything to ensure working of an invention in this country.

Now a patent is a monopoly, granted in the first place by reason of a statute passed in the reign of James 1st, granting monopolies to certain persons for terms of years. Out of these monopolies you are supposed to be able to make large sums of money, and have the sole right of using and selling within this country the article you have patented.

Therefore, you owe a duty not only to yourself but to the State which gives you this monopoly, and that duty to the State is supposed to be satisfied if you meet the reasonable requirements of the public, but it is argued with a good deal of force and equity that that does not go far enough. Not only should you satisfy the reasonable requirements of the public but you should produce the article within this Kingdom which gives you the monopoly and puts you in possession, for a small fee, of this valuable property. You should use and make within this Kingdom the patented article, in that way giving employment to a large number of your fellow-countrymen—from whom you derive this monopoly—and getting the money spent here instead of abroad. For my own part I can see no answer to the argument.

Most people think it is better to have a free trade system, by which goods of one country pass from one country into another; I would not dispute this, but what I do say is, that a patent stands on a different footing from all other classes of property. It is property conferred by reason of a monopoly, for which you do not pay anything like an adequate sum into the coffers of the State. In this way, in many cases, men, including

foreign patentees, make large fortunes outside this country, not benefiting us in any way except in so far as they introduce a new article, and certainly not doing anything to provide employment for the great population of the Kingdom.

As I have said, there is no other country in Europe where this condition exists. The United States makes no conditions as to working a patent within the country, but owing to the hedge of tariffs they place round any single article, there are very few cases in which it does not pay to make a patented article in the States instead of in this country. I do not know whether we ought to pass any resolutions on the matter; the Chamber of Commerce has taken it up with great vigour and we may, I think, safely leave it in their hands.

This power of monopoly by foreigners is, I may add, rendered all the more powerful by reason of another section of the Act, which permits a man to make an amendment in a specification if he finds it to be bad. It must be remembered that a specification is a legal document which sets forth, or ought to set forth fully and precisely the property to which you are laying claim, and every word in the document ought to be carefully studied and considered before it is put down, because unless you fully and accurately discribe your invention, unless your description is legally as well as technically accurate, you are liable to have the patent declared invalid by reason of wrongful description. If, however, you find your patent is not good, you can amend it, and when you have amended it the law says:—"Leave to amend shall be conclusive as to the right to make the amendment allowed except in case of fraud, and the amendment shall in all courts and for all purposes be deemed to form part of the specification."

Now that clause, which has appeared for a good many years to be a mild and innocuous one, has received a good deal

more force by a decision of the House of Lords given three or four years ago, in which they declared it meant this, that an amended specification should stand in the place of the original one, and that it should not be competent for anyone to go behind that specification in order to see what the nature of the original specification was. Further, whereas the old practice of the Patent Office was, when an amendment was made, to insert in italics all the added words, and to run a line through all the words taken out, their practice is now to issue the specification as amended, without any clue whatever as to the nature of the amendment which has been made.

Now take the case of a chemical patent—and this often happens—in which a chemist working in a large establishment in Germany, finds out a new reaction from a certain series of elements, he then gets a text book and takes out of it every reaction which can be possibly brought within the limit of his invention and adds them to the specification, and if any small maker in this country makes one of these compounds, an action is brought, involving great cost, and after putting the Defendant to enormous expense, the Plaintiff amends by striking out the whole of the excess matter in the specification.

You cannot go behind that amended specification and show the plot practised upon the public. Taken in conjunction with this enormous power of amendment in English Law, the provisions which at present exist with regard to the freedom of patentability by foreigners, render their position in this Kingdom a stronger one than they occupy in any other country in the world, and I make bold to say that these are the sole reasons, or nearly so, why in Germany there is such an enormous aniline dye industry and why in this country it is only represented by one or two firms. This question does not apply to quite the same degree in mechanical patents, but it is always there. I am glad the Chamber of Commerce has taken it up, and hope

the results of their labours will be to secure a very considerable amendment in the Law.

The President, in concluding, expressed the hope that the present Session would be a profitable and pleasing one, and made an appeal to the members to endeavour to make the "topical evenings"—now introduced for the first time—successful, as the object of them was to bring more members into the discussions than was usual when a set paper was read, and to offer opportunities for mutual help amongst the members on any questions which might crop up. He hoped the encouragement which would be given to this new scheme would be such as to induce future Councils to carry it on so long as the Society lasted.

On the conclusion of the President's remarks, the Meeting resolved itself in a social gathering for the remainder of the evening.

ROLLER BEARINGS AND THEIR APPLICATIONS.

READ SATURDAY, 23RD OCTOBER, 1897,

BY

Mr. THOMAS W. HOW, F.I.S.,

LONDON.

As the application of rolling motion to bearings is at the present time exciting much attention, the author ventures to hope that the matter contained in the following paper will be acceptable to the members of this Association.

The subject may be divided into the following heads :—

I. The advantages arising from the application of roller bearings.

II. The requirements and details of construction of such bearings.

III. The results already obtained from roller bearings which have been applied to railway vehicles, tramway cars, and other purposes.

I.—The Advantages arising from the application of Roller Bearings.

The principal advantages arising from the application of roller bearings are the following :—

Reduction in starting effort.

Decreased tractive effort in the case of vehicles, whether running on ordinary roads, tramways, or railways.

Decreased resistance to rotation in the case of shafts and other revolving mechanisms.

Avoidance of hot bearings and economy in lubrication.

The vital importance of reducing starting effort and tractive force to the lowest possible point, is well illustrated by the

amount of labour and capital which has been expended with results generally satisfactory, from an economic point of view, upon the construction of the road, railway and tramway systems of the world. The primary object of such systems is to reduce the force necessary to accomplish the transportation of people and merchandise, and as a consequence to effect such transportation at the least possible monetary cost.

It is interesting to note that very early in history the advantages of rolling motion were discovered. The Ancients quickly appreciated the advantages of placing heavy loads upon rollers or wheels when desirous of moving them, rather than attempt to do so by sliding them over the surface of the ground. In other words, the advantages arising from the use of rolling, as compared with sliding friction, were so obvious as to ensure universal adoption of the principle.

Having obtained such good results from the adaptation of rollers or wheels for tractive purposes, it is strange that such a long period should have elapsed before any serious attempt was made to apply the same kind of motion between the wheels and their axles in the case of wheels revolving on fixed axles, or between the axle journals and their bearings, in the case of axles revolving in fixed bearings, as had been found so advantageous when acting between the rims of the wheels and the surfaces upon which they moved, the earliest of such attempts being so far as the author is aware of quite modern date.

The importance of reducing frictional resistance both in starting and running is now fully acknowledged and is emphasised by the many anti-friction metals and special devices for improved lubrication of axles and shafts now on the market. Whatever degree of success the best of these devices may have attained they cannot approach such favourable results as are produced by the application of properly constructed roller

bearings. With reference to this part of the question, the following extract from a paper read at the Toronto Meeting of the British Association in August last, by Mr. Bayley Marshall, M.Inst.C.E., is interesting :—

"*Reduction in Starting Effort.*—The reduction in the effort required to start vehicles or shafts fitted with roller bearings as compared with those fitted with ordinary bearings is of such importance that, if it were the only advantage, it would warrant the necessary additional monetary expenditure.

"In the case of steam, electrical or other mechanical traction, the reduction of starting effort allows of heavier trains or vehicles being controlled by the existing locomotives or other motors, than can at present be dealt with, and in many cases would avoid the necessity of a second locomotive.

"In the case of electrical traction, the reduced starting effort is of almost vital importance, as not only does it effect a very considerable saving in electrical output, but also greatly reduces the serious rush of current through the motors at the moment of starting, which rush is due to the fact that the motors and load have to be started at the same moment, with results most detrimental to the life of the motor. If the necessary effort can be materially reduced, there will be a large economy effected under the head of 'Maintenance of Motors.'

"In the case of horse traction, the starting of the load is, as in the case of electrical traction, the most trying part of the work, and the constant effort the horses have to make to overcome this resistance when employed on heavy draught work, such as omnibuses, tramcars, drays, railway carts, &c., &c., is the principal factor in reducing their lives to the

present low average. Undoubtedly, where vehicles are fitted with roller bearings, horses can perform their duties with much less distress than with vehicles fitted with ordinary bearings, a result greatly to be desired from a humane as well as from an economical point of view.

"*Decreased Tractive Force.*—Although it is not claimed that the reduction in tractive force will be so large in proportion to that in starting effort, it must be remembered that this force is in application during the whole of the time a vehicle is running on level ground or ascending gradients, this point, therefore, becomes of great importance when the total amount of work done is calculated.

"*Decreased Revolving Effort.*—This is of great economical value in all cases of heavily loaded shafting, as careful experiments have shown that the amount of power required to drive the main and counter shafts in workshops, all the tools being idle, amounts to as much as from 50 to 83 per cent. of the power required when all the tools are in full work; these figures show that there is ample room for improvement in shafting bearings.

"Another important field for the application of roller bearings is to the main and thrust bearings of propeller shafts. The author is not aware of any reliable data as to the percentage of engine power absorbed in overcoming the friction of these bearings as now constructed, but judging by analogy and from experiments on similar bearings, it must be very considerable.

"*Economy in Lubrication.*—This, though not of first importance, is a considerable item, seeing that a perfectly constructed roller bearing does not require any lubrication, but only sufficient oil need be applied to prevent the rusting of the various parts."

The author thinks it is only right that he should state that Mr. Marshall's favourable opinions were chiefly founded on the results of experiments and trials made with roller bearings of the design and character hereinafter described.

II.—The Requirements and Details of Construction of such Bearings.

The requirements of a satisfactory roller bearing may be stated as under.

1st. The rollers must be provided with sufficient bearing in lineal inches and be of sufficient diameter to withstand the stresses imposed upon them, and must also be made of suitable material.

2nd. The rollers must not be allowed to touch each other, they must be controlled against lateral motion, and must remain exactly parallel with the axis of the journal throughout their revolutions thereon, as any deviation from the latter requirement reduces the contact between the rollers and journal to a point, and sets up a spiral movement of the whole series of rollers upon the journal. If such movement is allowed it is fatal to the good working of the bearing.

3rd. That the moving parts must be proportioned so that only rolling movement takes place between the engaged surfaces.

4th. That the end thrust or tendency to lateral movement must be controlled not only in the case of the rollers themselves, but also of the axle or shaft in a fixed bearing, as for instance a railway axle, or of the bearing when revolving on a fixed axle, as does the ordinary road vehicle wheel.

5th. That the bearing must be as simple and as free from complications as possible.

6th. Dust and dirt must, as far as possible be excluded though their presence is not so injurious to roller as it is to ordinary bearings.

7th. If it is desired to make a commercial as well as a mechanical success of such bearings, they must be so constructed

that they can be produced at reasonable cost; they must not require special attention, and must be capable of long service, with small cost for maintenance.

Simple as the above requirements may appear, the author believes that the only bearings at present which approach their fulfilment are those he is about to describe, and it will be interesting to state shortly the steps by which the present design was reached.

In the first attempts the rollers were spaced by subsidiary rollers as shown in Plate 1 or by balls as shown in Plate 2. One such subsidiary roller or ball, being placed at each end between each pair of rollers so that in any bearing there was twice the number of subsidiary rollers or balls than of main rollers. It was found in the first place impossible to keep these spacers in their proper position, as there was a strong tendency for them to fly outwards, and in the second place there was nothing to prevent the whole combination taking a spiral form.

To overcome the first difficulty, floating rings were introduced as shown in Plates 3 and 4, and the results proved that a great step in advance had been made, but that the spiral action still remained. The next step was to connect the spacing subsidiary rollers or balls, or in other words to form them on the ends of rods, thus compelling both ends to move at the same velocity. The arrangement then became as shown on Plate 5, a form of bearing which has given excellent results, its only fault being that it contains too many working parts, and is consequently too costly for general application. In this form of bearing, when the various moving parts are properly proportioned, there is nothing but true rolling movement. The next step was to do away with the subsidiary or spacing rollers, and to introduce a floating cage in their place, this cage being so designed that although it acts as a spacer for the rollers it does not carry any of the load. The general arrangement of the bearing then became

as shown by Plate 6, and Fig. 1, Plate 7, of which Plate 6 is a cross section of the bearing, Plate 7, a longitudinal section, and Figs. 2 and 3, on Plate 7, details of the small bearing pieces which carry the ends of the rollers. This form of bearing has been applied amongst other purposes to "Great Paul," the big bell at St. Paul's Cathedral, London, with most satisfactory results. The next and final step was to do away with the conical points at ends of rollers and special bearing pieces in cage, and to make the rollers simple cylinders bearing on the spokes of the cage, as shown on Plate 8, and illustrated on the diagrams. This is the form of bearing recommended by the author, and is the one that has given the results set forth under heading III. It will be seen that there is only one moving part, namely, the cage, in addition to the rollers, and the only sliding friction in the arrangement is that between the rollers and their bearings on the cage, this is of very small amount, as it has only to overcome the resistance of the cage to revolution.

It is of interest to note that in this form of bearing the speed of revolution of the cage is only about one-third of that of the journal.

The above is a short description of the process of evolution of the latest form of Roller Bearing.

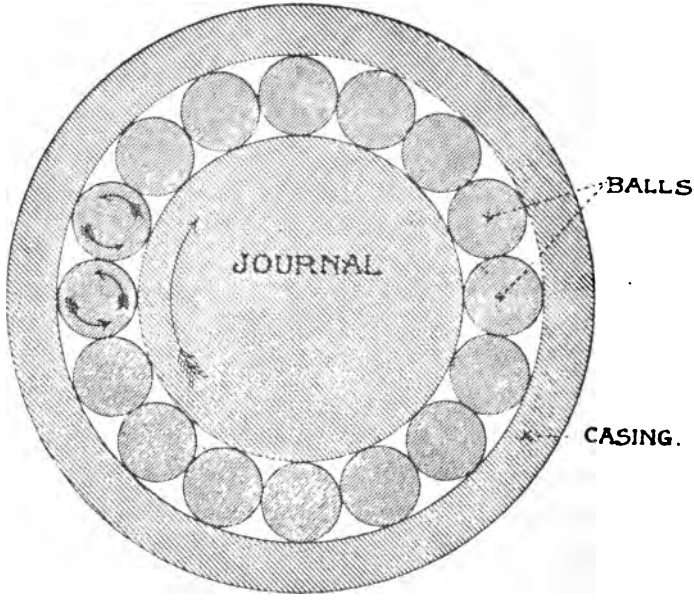
III.—The Results already obtained from Roller Bearings which have been applied to Railway Vehicles, Tramway Cars, and other purposes.

As to the results which have been obtained in practice from roller bearings :—

For many years the only successful application of rolling motion to bearings was the well-known "ball bearing" so universally adopted for cycles, and although these bearings have been found most satisfactory when

subjected to light loads, all attempts to apply them to heavy ones have, so far as the author knows, resulted in failure, these failures arising chiefly from the balls indenting the paths or races upon which they run. Directly this takes place the balls begin to lose their friction-reducing properties. If a semi-circular trough be constructed which accurately fits a ball, and after the ball is placed therein, one end of the trough is lifted until movement of the ball takes place, it will be found that the ball moves by sliding and not by rolling. This is indentation carried to its extreme limit.

Another defect in the ball bearing is that the balls are allowed to touch each other, and as the touching points of any two balls are revolving in opposite directions, there must be a certain amount of scrubbing friction between them. This is shewn by the following diagram : —



Roller bearings of the form which the author has described, and which are illustrated by the large diagram, are now coming into extensive use. Considerably over 1,000 of them have been supplied, or are in course of construction, and considering the short time they have been on the market, such results speak for themselves. The following list shows how general is the application of these bearings, which have been supplied to, or are in process of manufacture for many English and Foreign Tramways, and

Line Shafting.
Motor Cars.
Seed Crushing Mills.
Furnace Bottom Cars for Armour Plates.
Hand Trucks.
Engine Shafts.
Cycles.
Omnibuses.
Gas Traction Cars.
The Great Bell of St. Paul's, London. "Great Paul."
The "Monorail" Electrical Express Railway at Brussels,
&c., &c.

The following are amongst the most interesting results obtained.

RAILWAYS.

In railway vehicles fitted with these bearings the starting effort has, in many cases, been found to be as low as 8 lbs. per ton of load.

A passenger train of six carriages, fitted with roller bearings throughout, has been running for over two years between Brighton and Kemp Town, with a total mileage of over 70,000, and has shown a saving of from 12½ to 15 per cent. in the consumption of fuel, which saving has been obtained under most disadvantageous circumstances, inasmuch as the engine has to

be kept in steam for about sixteen hours per diem, whilst its actual running time is under seven hours.

The road between Brighton and Kemp Town is also a most trying one on account of its almost continuous curves, its constant stoppages necessitating great expenditure of brake power, and the abnormal number of points and crossings in so short a run, added to which a great portion of the line is laid with guard rails, so that the fixed charges of traction are in this case very heavy.

So well satisfied is the Brighton Railway Company with the extended trials as above-named, that orders have now been placed for roller bearings for main line traffic.

The Western Railway of France are fitting a complete train with roller bearings for experimental purposes, and their report will undoubtedly be of great value, as investigations of this kind are carried out with great care and skill by continental engineers.

The Liverpool Overhead Railway made their first trials with these roller bearings some two years ago, and are now gradually fitting them to the whole of their rolling stock, as they find that since their introduction they have, with a slight modification of their motors, been enabled to run three instead of two coach trains, the extra coach being without motors, thus increasing the carrying capacity of their trains by 50 per cent.

The contention that the application of roller bearings in the case of electrical traction will show a great economy under the head of "Maintenance of Motors," has been amply borne out by the experience gained at Liverpool.

The City and South London Railway are applying these bearings to their carriages.

TRAMWAYS.

The following are the results of careful experiments made to ascertain the relative starting effort and running friction of tramcars, fitted with ordinary and roller bearings.

Starting Effort.—Tramway cars, weighing 4 tons 15 cwts., ordinary bearings, 198 lbs. or 41·68 lbs. per ton ; roller bearings, 30 lbs. or 6·53 lbs. per ton—a saving of 84 per cent.

RUNNING FRICTION—GRAVITY TEST.

A tramway car, fitted with ordinary bearings and weighing 2 tons 15 cwt., was let loose from a point 56 feet up an incline, with 1 foot 6¼ inches rise. It ran down this incline and 57 feet along the level line at foot of same, or a total distance of 113 feet. The force expended was, therefore, 6,160 lbs. falling through 1·521, &c., feet, or 9,364 foot-lbs. The average frictional resistance was 9,364 ÷ 113, or nearly 83 lbs., equal to 30·5 lbs. per ton. A similar car fitted with roller bearings being let loose from the same point, ran the full length of the level line available, namely 320 feet, and had not then quite come to rest, the total distance traversed being 376 feet. The force expended was, again, 9,364 foot-lbs. The average frictional resistance was 9,364 ÷ 376—24·9 lbs., or about 9 lbs. per ton of load—a saving of 70 per cent.

The following figures are of interest and are founded on the results of actual experiments.

Relative starting effort of a tramcar on a gradient of 1 in 20, ordinary bearings 100, roller bearings 77, saving 23 per cent., ditto, ditto, on a gradient of 1 in 80, ordinary bearings 100, roller bearings 50, saving 50 per cent., ditto, ditto, on a gradient of 1 in 140, ordinary bearings 100, roller bearings 39·6, saving 60·4 per cent.—results which require no comment.

Roller bearings have been fitted to many horse cars, with results most beneficial to the animals employed, and it is estimated that the use of them would so prolong the life of the horses, that the reduction in their depreciation alone would show a saving of considerably over £10 per car per annum.

The Corporation of Blackpool have had some of their tramcars fitted with roller bearings, and these cars have been

running on their electric tramway for over three years, and with results so satisfactory, that they have applied similar bearings to all the new cars which have been constructed since the advantages of these bearings were established; and their consulting engineer some short time ago certified that at least 30 per cent. of electrical output is saved by the use of such bearings, as compared with those in ordinary use.

GENERAL APPLICATIONS.

Perhaps one of the most interesting amongst the general applications of these bearings is that of the big bell of St. Paul's Cathedral, "Great Paul," which with its headstock and other moving parts weighs nearly 25 tons, and which gave considerable trouble when mounted on ordinary bearings. The following results are instructive:—When mounted on the ordinary bearings the bell came to rest—after the swinging effort had been discontinued—within one minute, when on roller bearings in six minutes fifty-five seconds, showing that the frictional resistance of the latter was only about *one-seventh* of the former, a result remarkably in accordance with the starting effort tests given under the head of "Tramways."

An equally satisfactory result has been obtained from four bearings fitted to the main shaft of a heavy seed crushing mill at Hull, the estimated saving, arising from the alteration from ordinary to roller bearings, being at the rate of no less than £120 per annum, a saving that will repay the cost of such alteration in less than six months, and continue as an annuity for the remainder of the life of the bearings.

Two large bearings are now being manufactured for the main shaft of a large colliery ventilating fan for the North of England.

With reference to the question of heating, it is an interesting fact that there has not been a single case of a hot bearing in all the experience so far gained with roller bearings.

MAINTENANCE.

Although it is somewhat early to predict what the cost of maintaining these bearings will be, the results so far show that if they are constructed of suitable materials, it will be extremely low, 60,000 miles in railway work, and over three years in tramway work, with but very slight wear are most encouraging. It has been found that polished compressed steel is the best material for the rollers, cast steel for the cases in railway and heavy shafting bearings, and hard cast iron for tramcar and other lightly loaded and slow-running bearings.

The demand for these roller bearings is steadily increasing, and the results obtained from their practical application in every day use, justify the author in his conviction that the experimental stage of roller bearings is now past, and that as the demonstration of their utility and economy becomes more generally known and appreciated, their success is already assured, and their universal adoption is only a question of gradual, if not of rapid, development.

With regard to cost. It is scarcely fair, perhaps, to make an absolute comparison with the ordinary axle box bearing or plummer block at present in use, since the materials, workmanship and working parts are essentially different. Moreover, economies in machinery and manufacture which follow a large and increasing demand, cannot fail to exercise a beneficial effect in this respect, but generally it may be said that the present first cost is from two to three times that of an ordinary bearing of similar dimensions, which longer life and the economies effected in fuel, lubrication, and cost of labour in maintenance amply compensate for in ultimate or annual expenditure.

Many of the above facts are recorded in papers read by Mr. W. Bayley Marshall before the Institution of Civil Engineers, London, and the British Association, Toronto, in May and August last respectively, but in the author's opinion they are of

such interest and pregnant with such possibilities for the future, that he hopes no apology is needed from him for bringing them before the members of this Association. They are absolute results obtained from the forms of roller bearings he has described, these bearings being, so far as his information goes, the only successful ones for heavy loads at high speeds. He thinks enough has been said to show that there is likely to be a large development in the application of these bearings in the immediate future, and he also ventures to hope that the foregoing paper will be of use to those interested in the question.

The author, in conclusion, desires to express his obligations to Mr. W. H. Woodcock, M.Inst.C.E., the Engineer of the Roller-Bearings Co., Ltd., for much of the information and the technical results given in this paper.

DISCUSSION.

The PRESIDENT said with regard to the scrubbing action in ball bearings mentioned by the author he might mention that the use of rollers had been common in one machine in the cotton trade for a great number of years. This was for the pedal regulator of scutching machines, and one of the greatest improvements that had been made in the use of rollers in that particular connection had been this very separation of the rollers which acted on the two sides of a rising and falling lever, in order that the friction of the rollers upon themselves might not detract from the accuracy and delicacy of the regulating motion. In cotton machinery they had years ago come to practically the same point as that to which the author had arrived with regard to the scrubbing action between adjacent rollers or balls.

To all who travelled much by tramcar, it was obvious that the frequent stoppages involved an enormous strain upon the horses. In this city they had not yet got electric traction, but they were going to have it, and if the scheme presented to the Council was carried out, they would also have municipalisation of the tramways. It was therefore worth consideration by the Manchester authorities when dealing with the problems which would arise in introducing electric traction over the enormous area covered by the tramways, whether anything that would save power was not deserving of their attention. The Manchester tramways extended over a distance of something like nine miles from the centre of the city. The question of supplying the current was therefore a serious one, and although it would be quite impossible to feed the whole area from one central station, anything that would enable the cars to be drawn at less expenditure of power than otherwise, so that the number of stations could be diminished, would, if adopted, effect a considerable saving on the whole scheme.

The author had referred to propeller shafts. In the Liverpool Exhibition of 1886, Mr. Lionel B. Wells, then engineer to the Weaver Navigation, exhibited a thrust block bearing, in which the thrust was taken up by balls. He understood that the Weaver Navigation had several tug boats fitted with that type of bearing.

He presumed that the whole of the cages of rollers mentioned by the author were practically running in a bath of oil. The question of lubrication, however, was not mentioned, but he took it as a matter that was certain to have been attended to, as upon it depends very largely the success of any scheme for reducing friction.

With regard to cost, it was quite true a bearing of the kind described might cost a good deal more than ordinary bearings, and it was also true that they could get an ordinary bearing for a very

heavy shaft that would show little sign of wear after a good many years' running. That, however, did not preclude the probability that they would have to get such an area to absorb the pressure as would on the other hand give rise to a considerable amount of friction. If they wanted, in the running of a large shaft, to avoid heated bearings they must have ample area to reduce the pressure to something like a reasonable limit, and friction went on over the whole of that area. A roller bearing could be made to present less surface of friction than a bearing of the ordinary type, and this might compensate for the increased cost.

Mr. W. H. HUNTER, chief engineer of the Manchester Ship Canal Company, said the author had done good service in forcing upon their attention a matter which they were perhaps a little inclined to neglect. Personally, he had had in the past and still had every day some experience in the working of roller bearings of very large size. On the Manchester Ship Canal, there were a large number of flood sluices 30ft. wide, working under differential heads, varying from 13ft. to 16ft., every one of which carried its load on roller bearings on the principle patented by his old friend, Mr. Francis Stoney, who, he regretted to say, died a few weeks ago. The principle was exactly the same as that which was advocated in the paper—the conversion of sliding friction into rolling friction—and the sluices had been working for a number of years, many times each day, with admirable results. The projectors of the Panama Canal —who stated that they were determined to make that Canal and were even now going on with the work continuously—had informed him that in the large number of sluices they intended to erect, they too proposed to adopt the principle of roller bearings. Then again, on the Ship Canal there were a number of swing bridges, such as that at Trafford

Road, of which the working load was 1,700 tons, and Barton Aqueduct, with 1,400 tons load, all of which were carried on the same kind of free rollers, except that in the cases of the bridges, instead of being parallel sided, they were, of course, conical.

The whole secret of success in the design of roller bearings, whether large or small, depended upon the avoidance of undue unit stress. Formerly on swing bridges constructed in this country, the rollers were loaded to something like four tons per lineal inch. That was reduced by degrees, until in the latest practice in this country the load per lineal inch had been reduced to about 2,800 lbs., and in the United States and America to not more than half a ton. He had laid down the rule after a good deal of investigation, that in no case was the maximum load upon a free roller of large sizes to exceed 800 lbs. per lineal inch—in other words, that 3 in. carried a ton—a little consideration would make the reason for this light loading plain. Consider first the case of a ball bearing, in which the supported surface was ungrooved, and which was therefore the case of a plane supported by a sphere. Theoretically the load in this case was carried on a point, and therefore—a point having no magnitude—was infinite. Infinite loading is, however, in practice impossible, and what occurred in such a case was that deformation took place, the sphere was flattened into a spheroid and bedded itself into the plane until an area of contact sufficient to support the load was obtained.

Now let the sphere be replaced by a cylinder, let a roller take the place of the ball. The load was now supported by a line, which was length without breadth. The load was therefore again theoretically infinite, and again deformation would take place in order to provide bearing area. The deformation might be very small—might be quite imperceptible by ordinary means of observation—yet would be appreciable in its effect. The

roller would become elliptical and would be indented into its bearings, and the flattening and indentation would be in direct proportion to the load.

Then arose a real difficulty in starting, as the roller had to be pushed out of the hollow it had made for itself in its bearings and at the same time the long diameter of the ellipse had to be turned up in the course of the revolution of the roller. Of course these points were below the limit of measurement, still they all had practical effect upon the working of roller bearings, therefore the essential feature was that rollers should be of such number as to reduce the unit stress to the lowest possible point. It struck him that the rollers shown on the diagrams were comparatively speaking too large and not sufficiently numerous.

The author had stated that rollers were used in times of ancient history and referred back to to the Greeks and Romans. They went still further back than that. They began to be used in the ancient land called in the speech of the Greeks—Mesopotamia—"the Land between the Rivers," and were introduced by the parents of civilisation—the nation that preceded the Assyrians and the Chaldeans, from which the Egyptian civilisation was in the first place derived.

He remembered an experiment made a number of years ago by Messrs. Easton & Anderson at their works, under the auspices and on the suggestion of the late Mr. Stoney. There they had on show a solid bed of cast iron, beautifully finished, carried upon the bed was another block of cast iron, weighing just a ton, and with its bearing face also exquisitely finished. The second block was supported by a number of polished steel rollers, each 1in. diameter, and from the end of that block was carried a green silk thread over a small pulley, in which there was a small scale-beam. In this they put 1 oz. and then 2 oz., and with a little over 2 oz. weight in the beam, the

block weighing a ton was moved over the polished face. He could, therefore, quite believe that examples had been found in which with roller bearings, a tractive force of 3 oz. per ton was sufficient to move a truck on a well-formed railway.

At one part of his paper the author told them that the cage in which the rollers were carried travelled at the rate of one-third of the velocity at which the journal itself was travelling. He did not quite understand that. Now in explaining what free rollers were, he had often used the following example:—Put a pencil upon the left hand, put the right hand above it, and you have a free roller, and by moving it you have the stroke of a free roller. It was therefore obvious to all that the roller travelled half the distance of that which was supported by the roller, and he could not understand how it was that the cage only travelled at one-third the rate of the journal, unless it was that the rollers were somewhat overloaded, and were therefore skidding in their seats.

He would like to know whether the company made the rollers or the seats of the harder material. It was obvious that whether the roller, journal, or seat was the hardest, the softer material would wear most. In the large roller bearings used in the canal bridges and sluices, they always made the rollers of somewhat softer material than the races on which they ran, simply because the rollers were renewed so much more readily than the races.

Mr. J. Parry asked for some information as to the diameter of the rollers and the load per inch of length. He would also like to know what kind of bearings were fitted on the tramcar with a resistance of 30lbs. per ton. About 8lbs. per ton was usually allowed in railway practice.

Mr. James Bolas said it was well known that an ordinary railway vehicle would start from rest and increase in

velocity on an incline of 1 in 100; which would give a starting fricton of 22·4 lbs. per ton. In the gravity tests mentioned, the vehicle with ordinary bearings had some 80lbs. per ton friction which seemed excessive. It was a fact that with tramway vehicles a great deal of the resistance, was due to the flange of the wheel being in the groove of the rail, and that if say two of the flanges were taken away the resistance was reduced by 50%. Whilst if a third flange was removed the resistance was further reduced. He could not understand how with ordinary tramway vehicles 8lbs. per ton could be obtained, even with no resistance in the bearings.

Then the author said there was a saving of 28% in starting friction on a certain incline, by the use of roller bearings, and on another a different percentage of saving. Now, starting friction was the same whatever the incline, whether 1 in 100 or 1 in 1,000; the force of gravity of course increasing the tractive effort required. He should like some information on this point how the varying percentages had been obtained.

As to the statement that ball bearings were not satisfactory for heavy loads, he had had experience in this direction, and at their establishment, they made presses with heavy revolving boxes carried on ball bearings, and they had large foundry cranes at work (which James Nasmith constructed in 1839) with ball bearings at the foot of the post, and these are running to-day in a satisfactory manner and had cost merely a nominal sum for repairs.

Mr. Hans Renold said although he had not much experience in roller bearings, he had made hundreds of thousands of feet of roller chains. There can be no doubt that a rolling motion is far to be preferred to a gliding motion. For this reason it is that for Cycle driving the roller chain is coming to the front again

after the block chain, which gives a gliding motion, has now had for several years the exclusive sway.

In 1892 he was over at a large manufacturing company's works in Providence, U.S.A., where they were just then very jubilant about the success achieved with some roller bearings. The Company wanted to do some "broaching"—or as we should call it here "drifting." They had a very large machine made by Pratt & Whitney for drifting large irregular holes. The machine had five pair of spur gears by which the power was thought to be obtained, but it would not work satisfactorily, and the result was that a machine costing several hundred pounds had been lying useless for two or three years. At last a "doctor" was found in the shape of a famous roller bearing manufacturer, who applied roller bearings to the machine, and soon got it satisfactorily to work by taking out three of the five pairs of spur gears.

The Mossberg people formerly of Attleborough, now of Providence, are making thousands of large and small rolling mills for which nothing but Roller bearings were used.

Roller bearings were sometimes ticklish things to deal with, and unless they were made most exact and accurate, and the material for the component parts judiciously chosen—the rollers being made softest metal—there would be nothing but trouble with them, but if the necessary care is taken they would do splendid service. He intended to go over to the States again next March, and ascertain the proper form of roller bearing for line shaft hangers for his own establishment. He was going to put roller bearings on all his hangers, and he anticipated that instead of requiring 27 HP for each motor, that this power could be reduced to 18 or 16 HP,

Before concluding, he should like to draw the members attention to a collection of letters first published by the editor of the "American Machinist"—who had been making a journey

in England and on the Continent—under the title of "America and its machinery, being a study of the European field for the introduction of American machinery." He recommended its serious perusal to the members.

Mr. J. H. BEASTOW asked if these roller bearings had ever been applied to details of machines. He had had some trouble with the slippers of the side bars of an engine, and took them off and put roller bearings in, two rollers at the bottom and two at the top. These proved very efficient, except for the noise they made. He should like to ask if they could be applied with adjustments for high speed machinery. He was very much struck that morning, in passing by a brick field—where all the bricks were made by machinery, pressed, and then put in a steam shed and packed—to note that the trucks all had roller bearings, which seemed to be in fairly good condition, notwithstanding the rough usage they received, and the simplicity of their construction. With respect to ball bearings, they could be used much more frequently in machine details than they had been. For the thrust of spindles, of drills and of headstocks they seemed to come in very well if they had some device or cage to prevent the balls from touching each other.

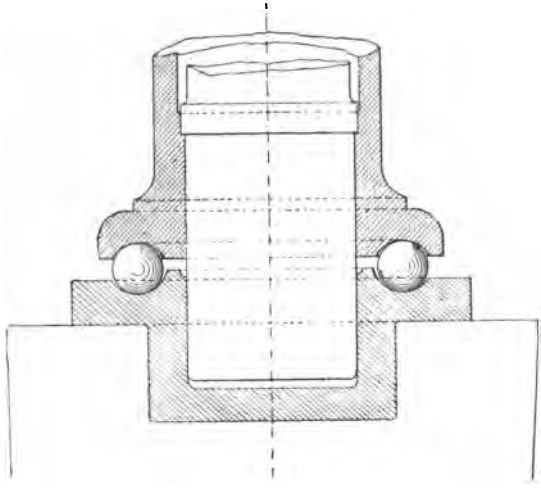
Mr. T. DANIELS said he always made the rollers in bearings of the softer material, in order to save the casing, and thought that was the better plan.

With regard to the ball bearings brought out by Nasmyth in connection with foundry cranes, one set of balls had lasted about 15 years, with very little wear. (See illustration.)

Roller bearings would do very well for wagons, carriages and tram cars; but not for locomotive engine axles.

The advantages of roller bearings had been proved. It was now a question of getting special machinery, to produce

them more cheaply, and he did not see why this should not be accomplished.



Mr. T. WALTON asked whether the large ventilating fan for which roller bearings were being made, was direct driven. (AUTHOR: Yes). It would then take the full thrust from the engine.

On Plates 1, 2, and 7 there appeared to be a shell or casing put on the end of the shaft. What was the reason for this?

Mr. G. LEWIS said however accurately made the rollers were, and however well chosen the material in which they ran, there must be a friction between the case itself and the roller in order to keep them separate. He had some experience with the ball bearings and tried to overcome the friction which two balls had on each other, by placing an intermediate smaller ball between them. In slow bearings he found that balls if made very accurately never produced any objectionable amount of friction.

Roller bearings had one objection. It was not easy to apply them to ordinary existing engines, but there was no doubt a great field for them.

Mr. Woodcock, engineer to the Roller Bearing Company, answered the technical questions raised during the discussion.

They found it a decided advantage that the bearings should run in oil, and found that the oil lasted very much longer than when applied to an ordinary rubbing bearing. He would explain the method of lubrication after the meeting by a reference to apparatus exhibited in the room.

He had had considerable experience in connection with swing bridges and ordinary bridges, and on the question of safe load per lineal inch on the roller bearing, he might say that this depended to a very considerable extent upon the diameter of the roller. They could put a heavier load per lineal inch on a large roller than on a small one, but against that there was the disadvantage that when larger rollers were applied they got fewer points of contact between the journal and its casing. Their practice was to consider that one roller might do the whole of the work of the bearing, and where possible they kept the load on that roller to a maximum of half a ton. per lineal inch. On rollers of not less than $1\frac{3}{4}$ inches in diameter, it was of decided advantage to make the rollers softer than the casing or journal, for the simple reason that they were so easily replaced. If the journal wore, it meant considerable cost in maintainance, whereas the rollers were comparatively cheap, and could be applied without putting the axle into the lathe at all, and consequently were easily replaced.

The great advantage of the roller bearing was its ease of starting. The larger the roller the less indentation or distortion was there between the surfaces, whilst it did not punish the journal nearly so much as the smaller one.

As to the relative speed of the cage and the journal, the reference in the paper should have been to the relative "number of revolutions." As Mr. Hunter explained, first there was the proportion of two to one. Then in this case the roller took its speed from the peripheral speed of the journal. The relation varied in proportion, but the author gave the relation in ordinary railway practice, which was three revolutions of the journal between the revolution of the cage and rollers.

As to the relative diameter of the rollers to length, this varied between $\frac{1}{7}$ and $\frac{1}{6}$. The relation between the diameter of the roller and that of the journal depended upon the number of rollers put into the bearings. If they put eight rollers into the bearings, which was now a very common practice, the diameter of the roller became slightly less than half that of the journal. With $8\frac{3}{4}$in. journals for railway work, they used $1\frac{5}{8}$ rollers, which was rather less than half the diameter of the journal.

The gravity tests were not made on a specially selected day, and were made with tramcars, one of which was fitted with roller bearings and the other just as it was taken from the road. Though the starting effort in the latter case was undoubtedly high, it must not be considered as applying equally to railway work. They found as a rule that in railway vehicles fitted with the best forms of the ordinary bearings, the starting effort varied from as low as 8 to 10 or $10\frac{1}{2}$ lbs., if everything was in first-rate order and on a good road, whereas with roller bearings it is only 8 lbs. per ton of load.

With regard to the question of heavy weights, they had in designing roller bearings to consider not only the weight but also the special shocks which they might have to stand, and also the speed at which the journal or the bearing, as the case might be, revolved. In the case of "Great Paul," there were 25 tons on the two bearings—$12\frac{1}{2}$ tons on each—and these were about $5\frac{1}{4}$ in. diameter, and the rim of the bell could be taken hold of

with one hand and moved easily. The starting effort then was very small indeed, but the velocity was also very low. No doubt a longer and larger bearing would be necessary if the velocity was high.

He had had an opportunity of making some experiments with Major General Hutchinson the other day on a railway, and the results were very interesting. They took two ordinary small four wheeled trucks such as were used in the iron districts for the carriage of pig iron, and one was fitted with ordinary, and the other with roller bearings. Each truck weighed 3¼ tons. They were let loose at a fixed point on an incline; the distance traversed was carefully measured, and levels were taken very carefully from the starting and stopping points. When the trucks were let go, without being loaded at all, the frictional resistance of the roller bearings was as 1 to 2·9 as compared with the ordinary bearings. When the trucks were loaded with 5 tons, the proportion was 1:2·67, with 10 tons the proportion was 1:3·9. Thus with the empty truck there was a saving of two-thirds, or 66%, and with the heaviest load, of 75% showing that with the roller bearing the frictional resistance did not go up absolutely with the load.

They had tried experiments with the bearings fittted with subsidiary rollers, and there was no scrubbing friction of any kind. They ran them three hours consecutively, and drove them at 5,000 revolutions per minute, without any sign of wear or heat. When they came to the cage, inasmuch as there was a certain amount of scrubbing friction, their must be lubrication. The greatest speed at which they had run the cage was on the Lartigne railway in Brussels, which had been run up to 70 or 80 miles per hour, with perfect success so far as the bearings were concerned. The best material for the cage was gun metal. The greatest wear in the cage was due to the end thrust. Their longest experience of the working of a cage was 60,000

to 70,000 miles, and in this case they had never had to replace anything, either rollers, cage, case, or journal.

The end thrust of the journal in axle boxes was taken upon a phosphor bronze pad. The thrust of the cage was taken as shown in diagrams. The tendency of the rollers to move laterally in the casing was taken by their infringing against the inner side of the cage.

The PRESIDENT (Mr. Nasmith), in moving a vote of thanks to the author for his interesting paper, said there was no question that the subject of roller bearings would have to be considered in this country.

Mr. T. ASHBURY, in seconding, remarked that the question of a reduction of friction was one which deserved the careful attention of all engineers. The lack of proper lubrication had a great deal to do with the wear of the end of the journals in railway wagons, and if the new journals were successful, it would be to the interest of railway companies to supply them. The present system of lubrication in railway wagons—principally by means of grease—was a barbarous one.

The motion was carried with acclamation.

Mr. T. W. How, in responding, said there was in the room a bearing which had run over 22,000 miles, and numerous other examples were shown to give the members an idea of the bearings he had been describing.

With regard to the starting effort, the Roller Bearings Company had at the Crystal Palace, London, an exhibit of wagons, and by means of these the starting effort could be tested. Engineers who had seen it were surprised at the ease of starting in the case of the wagon with roller bearings, which required an effort of 8lbs. per ton of load, as compared

with that fitted with ordinary bearings, which was at least six times as great.

He felt that no apology was needed for bringing the subject before the Association, and he was very gratified by the kind way in which his paper had been received.

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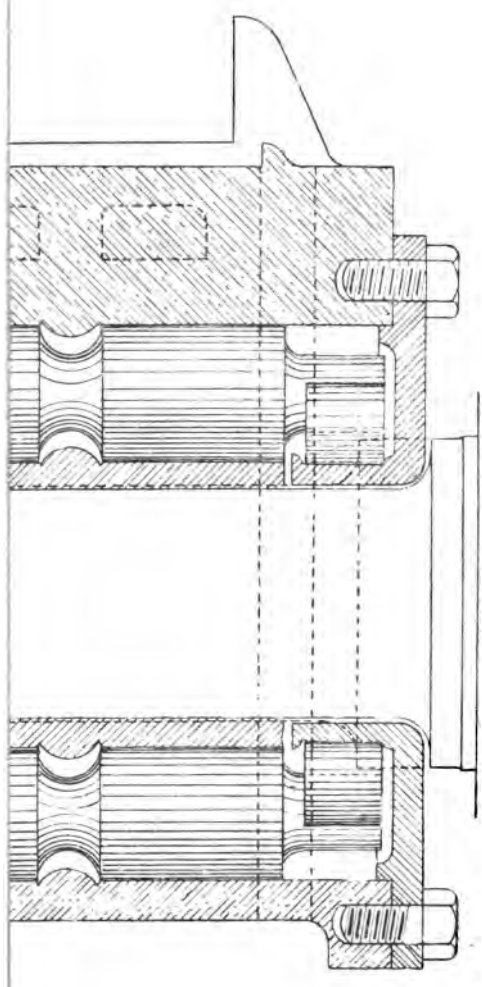
8 Plates follow illustrating this Paper.

Plate 1.

AND THEIR APPLICATIONS.

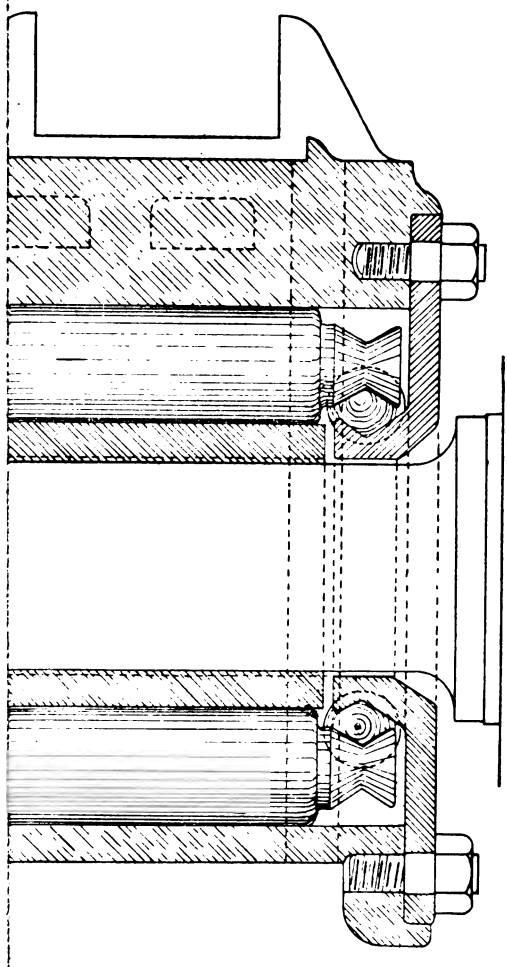


RY—ROLLERS AT EACH END.

(PATENT.)

Plate 2.

AND THEIR APPLICATIONS.

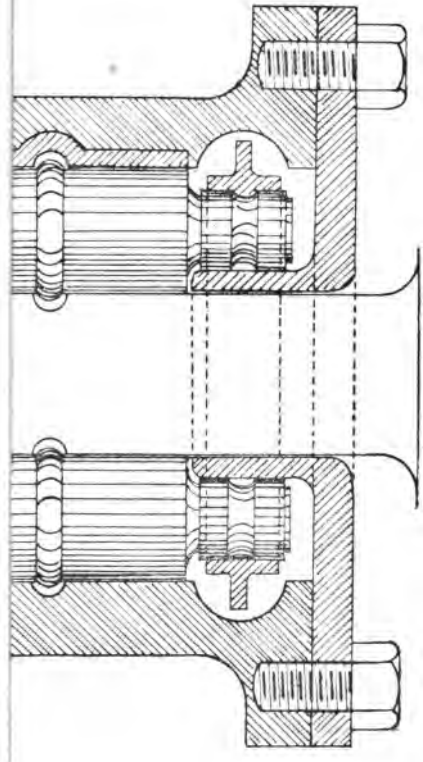


CING—BALLS.

(PATENT.)

UNIV. OF MICH.

ND THEIR APPLICATIONS.



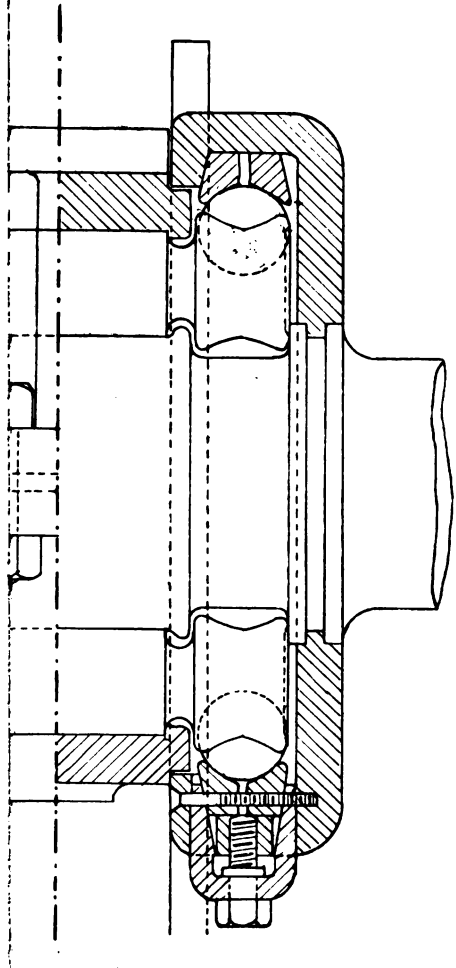
OLLERS WITH FLOATING RINGS.

(PATENT.)

UNIV
OF
MICH.

Plate 4.

AND THEIR APPLICATIONS.



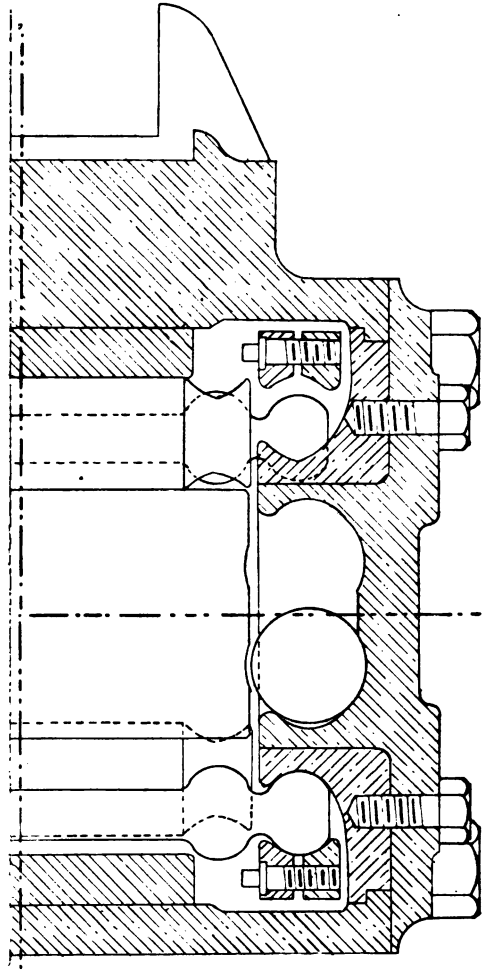
H OUTSIDE PATHS.

(PATENT.)

UNIV. OF MICH.

Plate 5.

ND THEIR APPLICATIONS.

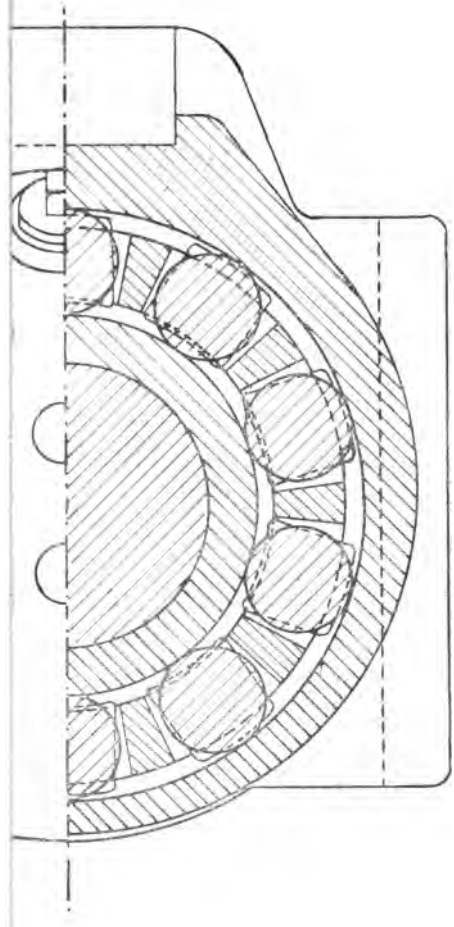


ROD ROLLERS.

(PATENT.)

UNIV OF NIGH

AND THEIR APPLICATIONS.



AGE—CROSS SECTION.

(PATENT.)

ND THEIR APPLICATIONS.

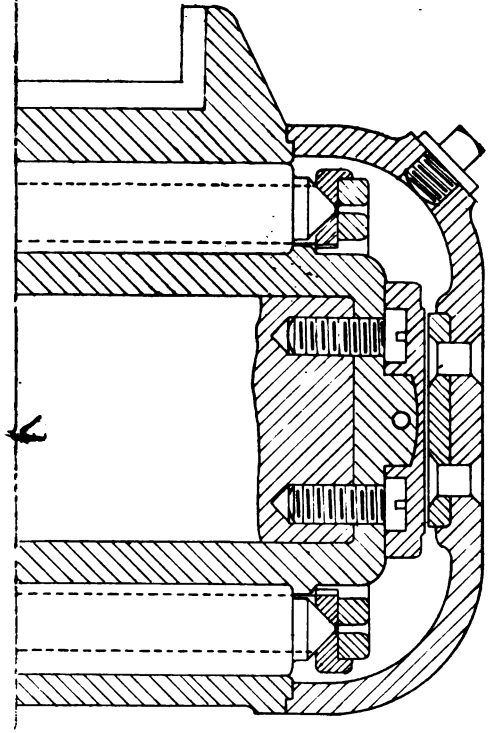


Fig. 1.

ONGITUDINAL SECTION.

PATENT.)

s. 2 and 3.

NG PIECES.

AND THEIR APPLICATIONS.

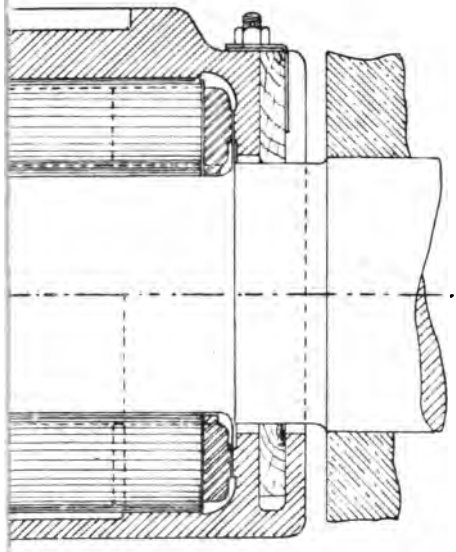
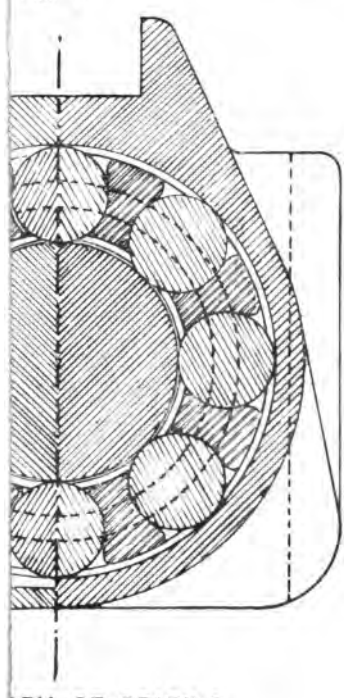


Fig. 1.



ORM OF BEARING.
(PATENT.)

TOPICAL QUESTIONS.

MEETING, SATURDAY, NOVEMBER 13TH, 1897

After the transaction of certain formal business the meeting was devoted to the discussion of Topical Questions, as indicated in the Syllabus.

The chair was occupied by the PRESIDENT, Mr. J. Nasmith.

The first question appertained to Ironfounding, introduced by Mr. J. POOLE, as follows :—

IRONFOUNDING.

Will the use of any of the Metallic Fluxes advertised, which are to be added to the metal when in the ladle, ensure the castings of cylinder liners, calendar bowls, doffer drums, cast iron shells, etc., being thoroughly sound and clear ?

Mr. HENRY WEBB said they could scarcely tell Mr. Poole what to do unless he told them something more about his castings. He should have given them the results of some test or analysis of the iron, and then they might be able to tell him what to do in order to obtain a perfect casting.

Mr. J. E. KELSALL said that for steel castings he could refer to the use of aluminium, from which they had derived very good results, and only a few weeks ago they made a large quantity of ferro-aluminium for the Aluminium Supply Company, of 10 % aluminium and 90 % iron, which would, he thought, give satisfactory results in the castings. He would, however, like to have more information as to the kind of metal Mr. Poole had been using.

Mr. POOLE said the iron used was about one-half machine scrap, which consisted of old looms and such machine scrap as

was generally got in the neighbourhood, and the other half best Scotch pig iron.

He had not made any chemical analysis of it. The advertisers of fluxes did not ask for a chemical analysis of the iron used, but stated that they would apply their flux, with advantage, to any ordinary iron at any foundry, and the iron they used was such as was likely to be used at any jobbing foundry.

The coke they used was specially prepared for foundry use, and the flux used in cupola was limestone.

Mr. J. WALTHEW said Mr. Poole wanted to make castings that would prove sound, and anyone who had any experience in foundry work knew that that was a very difficult thing. To find a means of accomplishing it would be a great boon to iron founders and engineers generally.

Mr. F. W. REED said he had some experience with the use of some of the metallic fluxes, and more particularly with ferro-aluminium. He had had castings made with a judicious use of ferro-aluminium (15lbs. to 20lbs. of 10% ferro-aluminium to the ton of iron) and taken particular notice of the machining and general quality, and had similar castings made without it, with equally good results. His experience was that ferro-aluminium was not the cure-all for the moulder. There were so many things that tended to make a good or bad casting that no one thing could be a cure-all. The qualities of ferro-aluminium were that it was a de-oxidiser, and had the power of converting combined carbon, into graphitic carbon. The judicious use of ferro-aluminium in light castings, such as those referred to, would probably have beneficial results, inasmuch as if the iron used was rather too hard it would tend to soften it, and it was important that castings of that kind should not be too hard;

and if there were any oxides in the metal the ferro-aluminium would tend to reduce them by fluxing them of. If, however, they wanted a casting, the special point of which was strength, they must not use ferro-aluminium, as the strength varied with the amount of combined carbon, and as before stated, the use of ferro-aluminium would convert the combined carbon into graphitic carbon, so that the strength would be reduced by using the ferro-aluminium. It was therefore evident that there were cases where ferro-aluminium could be used with advantage and others where it could not.

Mr. J. BUTTERWORTH said his firm, who were makers of piston rings, had great difficulty in getting sound castings, and decided to experiment with aluminium as a flux.

Having a large brass foundry they were able to melt the iron in crucibles and thus free it from the effects of bad coke and other impurities. They found that by adding ½oz. to the cwt. (to the crucible before pouring), a perceptible difference was made to the castings, as far as closeness of grain and cleanliness were concerned.

The difference was noticeable as it went into the crucible, as the metal seemed to grow more fluid. When 2 oz. to the cwt. was added, the effect was still more perceptible. The flux merely acted as a de-oxidiser and made the iron more like steel.

Mr. T. DANIELS said that the most important requisite in getting good castings was a good foreman moulder. With good metal, good moulding, good core-making, and other necessary precautions they would get good castings. He did not think the fluxes advertised would do away with all blow-holes, &c.

Mr. M. SWAIN said he could show castings $\frac{3}{16}$in. thick without blow-holes. He did not, however, use any scrap. He had a cupola that had been working 25 years, and was melting about

80 to 85 tons a day, making about 10,000 castings a week, and there were no specks or blow-holes in them. It was more a question of the workmanship than of fancy fluxes.

Mr. G. HUGHES observed that there was a good deal of truth in what Mr. Daniels had said. He might have added that they ought to get a man who was not afraid of hot metal.

The PRESIDENT said the conclusion seemed to be that aluminium fluxes might be of some value or might not, but were at any rate worth trying.

Mr. WORSLEY, foreman moulder, Dobson & Barlow, Limited, Bolton, said he had made a series of experiments in connection with pure aluminium, ferro-aluminium, and ferro-sodium. They could not use any of them without a reduction in strength. In every case where there had been a crucible test, or a cupola test, the results had been the same, so far as strength was concerned. In 1889 he made a crucible test with 1oz. of aluminium to 25lbs. of cast iron; a bar 1in. by 24in. broke at 10cwt. 3qrs.; ordinary iron broke at 12cwt. 1qr. Out of the same crucible he took half the metal and put aluminium in and took the other half and cast another lot of bars, and the results were in favour of the ordinary iron by nearly 2cwt.

In a cupola test with ¼oz. of aluminium to 21lbs. of iron, the iron was so weak that it would not stand the weight of the bar it was being tested with, but the ordinary iron stood 12cwt. 2qrs. On November 6, 1895, in a test of ¼oz. to 18½lbs. of iron, it stood 12cwt., and the ordinary iron 13cwt. 1qr. On November 7, 1895, a test of ¼oz. to 21¾lbs. gave 9cwt. 3qrs. 14lbs., and the ordinary iron 14cwt.

With regard to ferro-aluminium, in a cupola test of 6oz. ferro-aluminium to 168lbs. cast iron, the iron stood 9cwt. 3qrs., whereas the ordinary iron showed 15cwt. On November 12,

1897, he put 1½oz. ferro-aluminium to 150lbs. cast iron; the test gave 9cwt. 1qr. as compared with 11cwt. 2qrs. with the ordinary iron.

As to ferro-sodium, in March, 1896, he made a cupola test of 1lb. sodium to 168lbs. of iron, and it stood 12cwt., and the ordinary iron stood exactly the same weight. This was the first time such a thing had occurred in the series of experiments. On November 12, 1897, in a test with 1lb. sodium to 150lbs. cast iron, the result gave 9cwt. 1qr. as against 13cwt. 2qrs. with the ordinary iron.

With regard to the turning he had taken three samples, one of the ordinary iron, one cast from ferro-aluminium, and one from ferro-sodium. The ferro-aluminium iron was absolutely "kish" and completely "blown," not only outside but in. The ferro-sodium iron was a little better. The ordinary iron was absolutely clean. With regard to the interior the ordinary iron was close; the sodium was much opener; the ferro-aluminium iron was a little closer than the ferro-sodium.

It seemed to him that if Mr. Poole would only look to the charging, to the mixture of the iron and its quality, to the porosity of the sand, the dryness of the mould, and above all to the temperature of the iron, he would have no blow-holes, even if he used no flux. All that was needed was care. He should not use any scrap, but should get a particular class of pig iron and use it regularly. Either in thick or thin castings, if he used his metals in proper proportions he would get over all his difficulties. The temperature was a most important point. Whatever quality of iron or coke was used, if the temperature of the iron was not sufficient to overcome the amount of air in the mould, and the gases in the metal, the air itself would be stronger than the molten iron and they would have defective castings. On next page is a tabulated list of the tests referred to.

Test of Metallic Fluxes in Cast Iron.

Date.	Method.	Mixture.	Size of bar.	Breaking Weight at Centre. Cwts.	qrs.	lbs.	Remarks.
Nov. 26th, 1889.	Crucible.	1oz. Aluminium : 25lbs. Cast Iron.	1in. × 1in. × 24.	10	3	0	Put in the hot metal.
,,	,,	Ordinary Cast Iron.	,,	12	1	0	
,,	,,	1oz. Copper : 25lbs. Cast Iron.	,,	11	1	0	
,,	,,	Ordinary Cast Iron.	,,	11	0	0	
Nov. 6th, 1895.	Cupola.	½oz. Aluminium : 18½lbs. Cast Iron.	,,	12	0	0	
,,	,,	Ordinary Cast Iron.	,,	13	1	0	
7th,	,,	½oz. Aluminium : 21½lbs. Cast Iron.	,,	9	3	14	Metal poured on Aluminium.
,,	,,	Ordinary Cast Iron.	,,	14	0	0	
Nov. 28th, 1895.	,,	6oz. Ferro-Aluminium : 168lbs. Cast Iron.	,,	9	3	0	
,,	,,	Ordinary Cast Iron.	,,	15	0	0	
Nov. 12th, 1897.	,,	1½oz. Ferro-Aluminium : 150lbs. Cast Iron.	,,	9	1	0	*See foot-note.
,,	,,	Ordinary Cast Iron.	,,	11	2	0	†See foot-note.
		Ferro-Sodium.					
Mar. 17th, 1896.	Cupola.	1lb. Ferro-Sodium : 168lbs. Cast Iron.	,,	12	0	0	
,,	,,	Ordinary Cast Iron.	,,	12	0	0	
Nov. 12th, 1897.	,,	1lb. Ferro-Sodium : 150lbs. Cast Iron.	,,	9	1	0	‡See foot-note.
,,	,,	Ordinary Cast Iron.	,,	13	2	0	

* Metal pellety in appearance, darker in centre of casting than † also more open.

† Metal ordinary mixing solid, and close grain in appearance.

‡ Metal extremely pellety and kish, darker in centre than Ferro-Aluminium * and more open.

Mr. E. G. CONSTANTINE said the idea in using ferro-aluminium was to put it into a ladle containing molten metal. The ferro diffused itself amongst the mass, and its specific gravity being less than iron, it rose to the surface and in doing so carried with it a great deal of the oxygen and other impurities which might possibly exist in the molten metal when it hardened. There was no question that many castings were ruined through the metal not being hot enough to start with. There were different kinds of ferro-aluminium, and unless they got a good uniform quality they were apt to be deceived.

The effect on the strength of the casting must of course depend upon the amount of ferro put in. If a large quantity was put in, it certainly weakened the metal. The ferro was, however, not used in relation to strength, but to avoid impurities and blow holes, &c.; but it is obvious that if the metal is rendered of greater density the strength should also be increased. Many important engine building and machine tool making firms used ferro-aluminium regularly, and they would certainly not do so unless they were getting, or thought they were getting, benefit from it.

There was a difficulty in connection with alloys in obtaining them properly mixed, and that might explain the failure of them in many cases.

"WIRE DRAWN" STEAM.

What becomes of the heat lost in Wire-drawing? Is it all spent in converting the particles of water on the initial side into dry steam on the lower side, or is the fall in temperature to be explained in some other way?

Introduced by Mr. John J. Royle.

Mr. ROYLE, in briefly introducing his query, said: From the time of James Watt, when steam began to be used expansively, this has been a debatable subject. The old bone of contention

as to whether the same results could not be got by wire-drawing through a throttle valve in lieu of expanding in a cylinder has long been settled in favour of expansion, but periodically the question of the advantage arising from wire-drawn steam comes up again. At the present time it is up for consideration in relation to the high pressures carried in marine boilers of the tubular type, where the steam is raised in the boiler to 250lbs. and passed to the engines at, say, 180lbs., through some form of reducing valve. What change takes place in the steam after passing the reducing valve, and why, is the problem I desire to place before this meeting for discussion.

It is very generally assumed that the steam on the low pressure side of such a valve is super-heated or raised in temperature to a considerable extent, and that is the chief advantage of wire-drawing. I was of that opinion myself until I had an opportunity some time ago, by the kindness of the Engineer of the Wearmouth Colliery—and indeed at his suggestion—of making an exhaustive test of a wire-drawing case and ascertaining what actually did occur.

At this colliery the engineer had arranged a battery of five Lancashire boilers carrying steam at 68lbs. The steam was led off to the winding engine through a 13in. reducing valve at a uniform pressure of 30lbs. In order to ascertain what did happen the engineer had steam thermometers inserted into the pipes on the high and low pressure sides of the reducing valve respectively, and the following is what they revealed :—

The steam on the initial side was 68lbs. by the gauge and the corresponding temperature should be 313·6° Fah., but the thermometer showed 312° Fah., which, allowing for the mercury well and the thickness of the pipe may be taken as fairly accurate. The pressure on the reduced side was 30lbs. on the gauge, and the corresponding temperature of steam at this pressure is 273° Fah. The thermometer showed 275° Fah.,

showing that the steam was super-heated to the extent of 2° Fah. only, or if we allow 1° Fah. for imperfect conductivity, as on the initial side, it was superheated to the extent of 3° Fah. only. The temperature of the steam after passing the valve had fallen from 312° Fah. to 275° Fah., or a drop of 37° Fah. The experiment settled the point that steam wire-drawn in this way drops in temperature on the low pressure side to nearly the theoretical temperature appertaining to the reduced pressure, and that the generally accepted idea that it is considerably superheated is wrong.

Now what had become of this heat? That it had gone was apparent. That it could not have gone in radiation was equally certain, because the volume of steam passing precluded such a theory. Had it gone in drying the steam or vapourising the particles of water carried mechanically on the high pressure side and thus making it a more perfect gas? Or can it be argued that the fall in temperature was due to work done by each successive volume of steam as it passed the valve pushing the preceding volume in front of it, so to speak, and so doing work? Or is it some combination of the two theories that explains the result? That is the problem I propose to this meeting for discussion.

There were two things to consider in connection with this case. First, there was the statement of fact. It was generally supposed that if steam was wire-drawn the reading of the thermometer on the low pressure side would be considerably above the temperature corresponding to the lower pressure, but the test showed that there were only two degrees of difference in temperature between them, so that the theory that the steam was hotter than if generated in a boiler and passed direct was wrong. Still, something had happened, and there was no doubt that steam wire-drawn in the above manner had a very marked effect upon the working of engines, and very practical

results accrued from it. The problem was, what had become of the heat; could it be explained by the evaporation of the water mechanically carried on the high pressure side, or had it done work in expanding, and in that way having expended its energy caused the temperature to fall.

Mr. W. INGHAM said he supposed Mr. Royle had carefully tested his pressure gauges and thermometers. There could, he said, be little doubt that dry steam when wire-drawn was superheated. This theory was the basis of working of a number of Throttling Calorimeters. If there was any moisture in the steam and it was expanded from a higher to a lower pressure without doing work, there was no real loss of heat, and the moisture was evaporated into steam, or superheating took place. Up to about 2½% they could test very accurately the amount of moisture in wet steam of 80lbs. pressure. Throttling Calorimeters were, however, not applicable for a greater percentage than 2½% at a pressure of 80lbs., although for higher pressures, say for instance 250lbs., they may be used to compute up to 7% of moisture.

In the case at Wearmouth there was, he understood, a great saving made, which appeared to be attributed solely to the reducing valves. He apprehended that a number of other changes were made at the same time. The egg-end boilers, he believed, were substituted by Lancashire boilers of higher pressure, which might account for some portion of the economy.

If they wire-drew steam and superheated it they got the advantage in the steam-engine cylinders. If moist steam was used there was a great loss through cylinder condensation and radiation which superheated steam prevented.

In answer to Mr. Royle's question, he thought it had been abundantly proved, by very careful scientific observation, that

in wire-drawing steam from a higher to a lower pressure the steam was dried very considerably and cylinder condensation was reduced, and there was a great saving in that respect.

The gas in expanding against a pressure of 80lbs. undoubtedly did work, a portion of which was no doubt transferred to the engine cylinder, as Mr. Royle suggested, but he should imagine the great advantage arose from the drying of the steam and the diminished loss from cylinder condensation.

Mr. Joseph Parry said the work seemed to be done partly in pushing the steam forward in the cylinder.

Mr. H. Hodgson said there was no question that the loss of temperature was taken up by the re-evaporation of the water carried through by the boiler steam. This was abundantly proved by cases where the engine was working under a light load. In the case in question there might just be a combination of circumstances which accounted for the temperature being practically that due to its pressure. It was not one case of this kind that will settle the point.

The continental engineers nearly all worked with a high pressure in their boilers, but did not use it in the engine; they throttled it between, and this was a method of super-heating; of which he was not quite sure that it was not the best.

Mr. Royle said Mr. Ingham had put before them two theories, that of re-evaporation and that of work being done by pushing the steam in front to the cylinder. They could not hold two theories at the same time. Which must they accept? His own opinion inclined to the more scientific view that the fall in temperature was due to re-evaporation, but here was the other theory, and they could not intelligently adhere to both.

He had not based his statement of the economy of wire-drawn steam alone on the particular case mentioned where there was a

change of boilers. He expected shortly to have an opportunity of practically testing the economy of wire-drawn steam, and he would bring the results before the members.

He had been very careful as to the instruments used and the thermometers, and had used three thermometers, which gave practically the same results. The pressure gauges were also very accurate.

The steam on the low pressure side was undoubtedly a more perfect gas than that on the high pressure side; it was a dried steam, but not a superheated steam, and he did not know of a word in the English engineering vocabulary that would quite accurately describe it.

Mr. INGHAM said he had made some tests about six months ago with a Throttling Calorimeter. The temperature on the low pressure side was very considerably higher than the normal temperature for the pressure. In that case it was very considerably superheated, so that Mr. Royle should not draw his conclusions too hastily as to superheating. He did not see why they could not accept both theories mentioned with regard to Mr. Royle's experiment; there might be both reduction of temperature due to re-evaporation and a further reduction of temperature owing to actual work done.

Mr. ROYLE said the steam was ordinary boiler steam. There were five good Lancashire boilers 30ft. by 7ft., which were fired easily, with no priming. The reducing valve was within 6ft. of the stop valve. The pipes were carefully lagged.

CLEARANCE SPACES.

What is the comparative influence of Clearance Spaces in high and low speed engines?

Introduced by Mr. A. Saxon.

Mr. ALFRED SAXON said: The question which I have been asked to introduce refers to "Clearance Spaces" in steam engine cylinders, and the point suggested for discussion is "What is the comparative influence of Clearance Spaces in high and low speed engines."

Before entering into details I wish to state that cylinder clearances may be divided into two kinds, the clearance in the cylinder proper and the clearance in the steam ports and passages from the valve face to the cylinder barrel. In practice it is found that cylinder clearances are a necessity. In the cylinder barrel sufficient space is necessary between the piston and cylinder cover to admit the requisite quantity of steam in a little time and to allow for expansion of rods and variations in length which occur through wear; clearance is also a necessity as a precaution against water in the cylinder.

The clearance in the port or steam passage to the cylinder barrel is undoubtedly a source of waste. The cylinder of an ideal engine would be so arranged that at the end of the piston stroke no space whatever would exist between the valve face and the cylinder barrel.

I must now deal with the clearances in long stroke and short stroke cylinders, this perhaps being a clearer definition for our purpose than high and low speed engines, because all high speed engines are necessarily made with a short stroke, and most low speed engines with a long stroke. In both kinds the ports are proportioned to the area of the piston and its speed, and not to the stroke; therefore, supposing for a moment the *clearance passages* in two cylinders, one with a long stroke and the other with a short stroke, to be of equal length, the short stroke cylinder has the greatest clearance space in relation to the cylinder volume or piston displacement.

The type of valve used is an important consideration in regard to port and passage clearances, the slow running type of engine

having an advantage in the use of the Corliss Valves, with automatic cut-off gear, which allow full port opening with short steam passage, and do not wire-draw the steam as is the case with many of the types of valves used in connection with high speed engines. The high speeds somewhat prevent the use of Corliss gears, and therefore a type of valve is often used which causes longer steam passages to the cylinder barrel. This, however, does not apply to Willans' Central Valve Engine, in which it is claimed to have the least possible clearance.

The surface of the cylinder walls in short stroke cylinders is considerable compared with the enclosed volume of steam, but against this it is claimed that the increased speed reduces condensation through the shorter exposures of the cylinder surfaces to cooling by exhaust steam, and then by shorter exposures to the entering steam to surfaces thus cooled. Against this it may be said of long stroke engines that the exposures are less frequent if longer in duration.

In high speed engines a large amount of cushioning or compression is found to be necessary to arrest gradually the momentum of the moving parts; this may have the effect of reducing the losses due to clearances in raising by this means the pressure of the steam remaining in the cylinder nearer to the initial pressure of the entering steam, whereas in slow speed engines compression is not usually adopted to the same extent.

At the summer meeting of the Institution of Mechanical Engineers, a report of which is given in the *Engineer* of August 6th, Mr. Morcom (of Messrs. Bellis & Co.), in reply to a criticism on cylinder clearances, made the following reply: He said they had found by experience that the difficulties due to clearance could be quite overcome by due attention to compression, and he did not think it mattered whether the clearance was a $\frac{1}{4}$ or $\frac{1}{8}$ of an inch so long as the compression was properly arranged. Speaking of their engines and the statements with

regard to economy made, he said that at any rate these were the results that had been obtained.

Mr. W. INGHAM said compression was very necessary. In indicator diagrams he had seen from some locomotive engines the compression was 10 to 20lbs. higher than the boiler pressure, and in such cases a large amount of clearance space was an absolute necessity.

Mr. H. HODGSON said compression was an absolute necessity for quiet running. There was no question in his mind that compression was also conducive to economy. On the question of clearances his basis of working was that the clearance in the low pressure cylinder should be as little as possible, but in the other cylinders of compound and multiple compound engines, the clearance space is a matter of less moment.

Mr. Saxon had spoken of the Corliss valve as being the one which gave the least amount of clearance; that was not his own experience. The Corliss valve, if they took into account all the clearance spaces, no matter where they placed the exhaust, absorbed a very considerable amount of clearance. The Corliss valve was the best for the governing cylinder, but he did not apply it for the intermediate or low pressure of compound or multiple compounds. As to the Willans' engine and its small clearance, what good had it done? There were engines running more economically where less attention was paid to clearances.

Mr. J. PARRY said they had to give $\frac{3}{8}$ to $\frac{5}{16}$ clearance in locomotives, and they never bothered further about it.

Mr. J. SAXON said they knew that if in a slow speed engine there was too much compression, there was necessarily a loss of power.

A steamboat built for a company, was intended to go up a certain channel, down which a strong current ran, as this

passage would save 10 miles on the ordinary route. It was found, however, that the makers could not make it capable of doing what was required, so that it would have to go round the longer passage. After the boat had left the builders' hands the engineer of the steamboat company took it in hand, and reduced the compression on the cylinders, with the result that the boat was able to go up the shorter passage against the current, which it had never previously done.

The greater compression left on by the makers had evidently reduced the power of the engines. That would be the case in slow speed engines, because in them there was not that necessity for compression to bring the engine to a stop, as in the higher speed engines, but in the quicker speed engines, although there was greater clearance, yet the pressure was raised, so that it was an actual advantage at the finish in restarting and recharging the cylinder and giving higher initial pressure for the incoming steam.

Mr. MITTON referred to the difficulties in getting a suitable amount of compression in locomotive practice.

The PRESIDENT said the chief point was whether in a long stroke engine, if they had a smaller clearance space, the fact that it was filled so much oftener did not more than compensate for the greater clearance which existed in the slow-running engine. Had this factor anything to do with the value of the clearance spaces? It was purely and simply a question of area, multiplied by the time the area was filled. The value of compression no one doubted; it diminished initial condensation, and the only question was, did they not pay for it? In high speed engines it was necessary in order to bring the piston to rest, and the question was whether that compression was not doing so much work as to seriously detract from the value of the principle in quick, reciprocating engines.

HYDRAULIC PLANT FOR COMPRESSING AIR.

READ SATURDAY, 27TH NOVEMBER, 1897,

BY

MR. H. D. PEARSALL, M.INST.C.E.,

LONDON.

The term "Hydraulic plant for compressing air" may, of course, include all machinery for compressing air in which water takes any part. It should, however, certainly be restricted to the cases where water is the main agent, *i.e.*, to cases of the application of water *power* to the compression of air, and that is the sense in which the term is here used.

The most usual way of applying water power to this purpose is to cause the water to produce rotary motion in some sort of a wheel, and by means of this rotary motion to drive reciprocating pumps in which air is received and compressed.

This is obviously rather a roundabout process, involving the use of two distinct machines besides gear connecting them, and several conversions of energy.

It is, of course, well known that though energy is indestructible it cannot be changed from one form to another without loss, and consequently if there are several transformations of energy, there must be several losses. In converting the potential energy of water descending from a height into the rotary energy of a Turbine, from 20 to 25 % is usually lost. In the gear required to connect the wheel to the pumps there is also lost a percentage of the energy of the wheel, and in converting this energy to that of the reciprocating pistons, a third loss is suffered. The loss due to intermediate gear is frequently very considerable, because a Turbine necessarily runs at a high speed and the pumps must

run at a low speed. The consequence is that the net energy received by the pump piston is seldom more than half that of the original energy of the water and is often much less.

If, therefore, the power of the water could be applied more directly, we should expect to attain a great economy of power. Consequently, many efforts have been made to secure this object.

Obviously these considerations apply to the use of water power for any kind of pumping, *e.g.*, pumping water, as well as compressing, *i.e.*, pumping, air—but in the case of air compression there is still another reason for desiring the direct application of the power. All the work done in compressing air is converted into heat, but when air is compressed under such conditions that all the heat is instantly and entirely absorbed by surrounding solid or liquid bodies, only about half as much net work is exerted (if, for example, compression is to $\frac{1}{5}$ of original volume) as when no heat is thus absorbed. Therefore, it is obvious that it is of the highest importance to thus absorb heat during compression of air.

In compressing air in reciprocrating pumps, it is found practically impossible to absorb more than half the heat which is developed, and this is not surprising when we find that the greatest quantity of water which can practically be used, under the circumstances, for cooling, is about $\frac{2}{3}$ of the weight of the air compressed, while the quantity of heat to be removed is very large indeed, amounting to 58 heat units per pound of air when compressed to five atmospheres. But the quantity of water actually *available* when the motive power is water is never less than 1,000 times the weight of the air.

Hence the strongest reason for applying the water used for power directly to the air—that if it can be done it should result in very much more thorough absorption of heat than can be accomplished in any other way.

This analysis of the imperfection of air-compressing machinery is, of course, modern, but the practical result—that the inefficiency was very great—has been realised in a rough way ever since compressed air has been in common use, and, therefore, the attempts to apply the water directly have been many.

In this paper the author intends to confine his attention to those hydraulic air compressors which more or less perfectly attain this object. They may be divided into two classes :—

In that which will be mentioned first the compression is effected by the weight of a column of water of a height equal to the maximum pressure of the air measured in feet of water.

To obtain this pressure the water used as power is carried down a well or shaft and up again in an inverted syphon. The air to be compressed is diffused through the water in bubbles as small as possible and part of it is then carried down to the bottom of the well by the stream. That which arrives there is, of course, then subject to the pressure of the water column above it and is accordingly compressed, and means are provided for allowing it then to escape from the water before it can again expand.

This method is one of the very oldest known. One form of it is described by Pliny in the first century and even then was old. In modern times several different inventors have revived it, and it is connected with the names of Upham, Mowbray, Frizell, and C. H. Taylor.

In this machine, as might be expected, the compression is isothermal, and it is a very simple machine and has few working parts. It is, however, rather an expensive one, as for a pressure of five atmospheres it requires the sinking of a shaft 150ft. or more in depth below level of the tail race, with an enlarged chamber and some of the apparatus at the bottom of the shaft.

Moreover, when its principles are examined, it is found that the unavoidable losses connected with it are large, so that its theoretic efficiency is not very high. These may be chiefly embraced under the head of fluid friction due to the flow through a pipe 300ft. long and to eddies. The fluid friction is not merely that of water flowing through a pipe. The bubbles of air, although they descend with the water, do not descend as fast as the water. Consequently, the water is all the time passing the bubbles and the rubbing surface causing fluid friction is therefore the whole surface of innumerable bubbles of air, in addition to the surfaces of the pipe. The co-efficient of friction is, therefore, very much greater than that of water in a pipe. The efficiency actually realised in practice appears to have been about 55 % under the condition of using a very large pipe, a low fall, and a pressure of only four atmospheres. Both a higher fall and a higher pressure diminish the possible efficiency.

In the other class of machines having the same object water acts as a piston, compressing the air in a chamber provided for the purpose.

The earliest is probably due to Montgolfier, the inventor of gas balloons and of the hydraulic ram, about 100 years ago, who described and patented a modification of his hydraulic ram to be used for the compression of air.

It was quite a practicable machine, though possessing some complications which have been proved to be needless. But the reason why it has failed to come into use is the same reason which for so many years has confined the hydraulic ram for water raising to machinery of small and almost domestic size, viz., the construction of the main valve. In Montgolfier's machine the escape valve was similar to that of the Montgolfier water ram and it was operated, as that is, by the current of the escaping water. This necessarily limits these machines to a very small size, and as, when compressed air is wanted, it is

nearly always wanted in considerable quantity, this alone would naturally prevent any use being found for these machines.

That this construction was unsuitable for any large size one supposes should have been obvious; but as for 100 years in nearly all attempts to improve the ram they insisted on retaining it, it seems it was not obvious.

It was, however, abandoned in the next application of this principle which will be mentioned. This is the air compressor designed and used by Sommeiller in the excavation of the Mount Cenis tunnel. Plate 1 shows one of these machines. It consists of a pipe *f* leading from the source of supply, two valves *a* and *b*, a vertical pipe *c* in which air is compressed, and a valve *d* controlling the connection between this compression chamber and an air-vessel *v*.

The action was as follows :—

The valve *a* being shut, and valve *b* being open, water is standing in the horizontal pipe to level *e*, chamber *c* being full of air. Valve *b* is then closed and valve *a* opened. Water flows down the pipe *f* and up the pipe *c*, compressing the air and forcing it through the valve *d* into the air vessel. When the water has come to rest valve *a* is closed and valve *b* re-opened, thus emptying chamber *c*.

It is to be noted that the water does not act merely by its pressure. When it begins to flow the air in pipe *c* offers very little opposition to it, and therefore the water acquires a high velocity and momentum. As the air becomes compressed it offers more and more resistance to the water, and this resistance absorbs the momentum of the column of the water. The compression is effected therefore more by the momentum of the column of water than by its pressure. Hence it is essentially an hydraulic ram. The head of water was 85ft. and the air was compressed to six atmospheres.

Nothwithstanding numerous defects of design, these machines had considerable success. Ten of them were made, and after they had been in use three years at the Bardonnèche end of the Tunnel, six others were made for the Modane end of the tunnel, where the fall was only 35ft. In this latter installation a most remarkable course was adopted, the history of which is very instructive. The natural fall being only 35ft., the water was first pumped by water wheels to a reservoir at a height of 85ft., and then used with this fall in the compressors. But a little consideration shows that this was entirely needless. If instead of doing this the valves *a* and *b* had been worked in a different way, a fall of 35ft. would have compressed the air just as well as a fall of 85ft. The mean pressure due to compression to six atmospheres equals 61 feet of water. When the fall was 85ft. the water would give a mean pressure throughout the height of air column of 85ft. less the loss of effect from fluid friction, &c. Hence if the efficiency was 75 %, the flow of the water would be adequate to compress all the air above the level *e*. The gross energy developed would evidently be represented by 85ft. × height of air column.

Now with a fall or head of 35ft., suppose that after the chamber *c* was emptied of water through valve *b*, instead of then closing *b* before opening *a*, *a* had been opened while *b* still remained open. Water would then have flowed away through *b*, and when the column had acquired a certain velocity, *b* would be shut, and the compressing stroke would then take place. The energy available for compression would then be represented by length of column of water in pipe *f* × head due to velocity, + 35ft. × height of air column, and it is evident that by making this velocity a certain amount, that is by keeping valve *b* open a certain time, the amount of this energy can be made exactly as great (or greater if desired) than the energy that was developed under 85ft. head.

Instead, however, of making this simple change in method of operating, the engineer, though undoubtedly a very able man, adopted the absurd course previously referred to. It must have been that "he did not think of it"—a fate that happens to all of us sometimes. He was not alone in this, moreover, for none of the writers on the subject have perceived it either. It was unfortunate because, of course, handicapped with all the losses due to preliminary pumping of the water, the compressors at Modane could not show a good result and were eventually superseded and the development of this class of machinery was set back for 40 years from a misapprehension.

In fact, nothing more was done in this direction until the writer turned his attention to this subject a few years ago. It appeared to him then that the principle was certainly right. Sommeiller had proved that it was safe and effective even when imperfectly carried out, and the author came to the conclusion that the imperfections were solely questions of design capable of rectification, and that the losses of power which were unavoidable were very small, so that we might reasonably expect to realise a very high efficiency in a very simple and economical machine. In 1891, the author described in a paper in the Proceedings Inst. C.E., an engine of considerable size for pumping water on the principle of the hydraulic ram, and then mentioned that he had also made experiments in compressing air in the same manner. But a machine made expressly for this purpose has not yet been described in print, so the author will now give some account of one.

Plate 2 shows one of these engines erected on the River Kent, in Westmoreland, from the author's design.

This also consists of a pipe *f* from the source of supply, and a chamber *c* in which the air is compressed by the momentum of the water. But in this engine the method of using the water is that which the author suggested should have been used at Modane. The water runs freely away through the valve *a* for a

certain time in order that it may acquire a certain velocity and momentum. The valve is then closed and the energy available for compression is exactly as formulated above. Consequently, such an engine may be used on a fall however small.

It will be seen also that there is only one valve in place of Sommeiller's two.

The air-valve *g* admits a fresh supply of air into the receiver after the compression is accomplished, and also allows of the escape of some of this air while the main valve is closing, so that part of the water which flows in the main pipe during this time can rise freely in the chamber instead of having to find an exit through the narrowing orifice of the main valve. The valve *g* is closed by the water when it reaches a float *h* attached to a lever in connection with the valve.

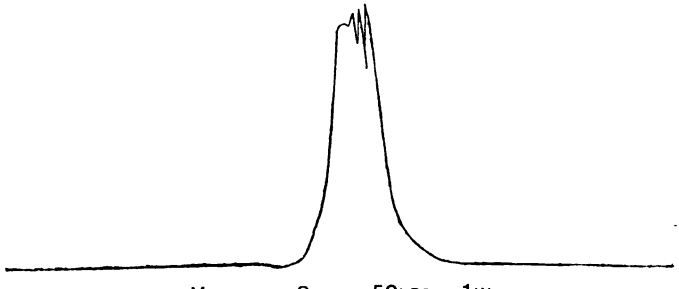
There being but one water valve, there is but little gear required to operate it, but it is necessary that the valve should open and shut at certain definite intervals of time. The author has used several different forms of gear for this purpose. In the earlier engines it was a cam, in the Kent engine it is a crank motion. In all cases the power to operate the gear is taken from the air-vessel. In the Kent engine water is used. In other cases an air motor has been used.

In the Sommeiller engine it was only possible to make three strokes per minute, probably on account of the imperfection of the way of operating the large valves, and because apparently certain pauses were necessary between each stroke. In this engine there are, of course, no pauses, and from 15 to 20 strokes are made per minute, so that an engine of given size will develop a much greater power.

The height of the chamber is also reduced one half by making its diameter half as large again as that of the main pipe.

The working of this engine has fully justified the author's expectations, which are referred to above. In the compression of the air practically all the heat developed is absorbed as it is developed; as indeed it seems obviously must be the case, for the compression is effected in a chamber which is cooled at every stroke by being filled with a mass of cold water, and therefore in the midst of a mass of cold wet cast iron on sides and top and of cold water below. The ribs of the valve plate further add to the mass of cold iron and to its surface. A registering thermometer was suspended in the air-vessel, and after several hours' running the highest temperature shown was about 2° above that of the water.

The engine runs with perfect smoothness and regularity without any noise (even as much as that of ordinary pumps) or concussions of any kind. It is essentially an hydraulic ram, and the popular idea of a ram appears to be that the essence of its action consists in a blow. This idea has, of course, no scientific foundation, but practice is perhaps more convincing than theory, and the fact is very practically demonstrated here. Below is an Indicator diagram taken from the compressing chamber during a stroke by a Crosby Indicator, such as is used for indicating steam engines. It shows the rise of pressure during compression, the existence of maximum pressure while the air is entering the air-vessel and its subsequent fall—a diagram in all respects similar to that of a piston compressor. No doubt



VERTICAL SCALE 50LBS. = 1IN.

the curve of compression would be an almost exact Hyperbola, but that it is distorted owing to the fact that the velocity of the water piston is a varying velocity, and the drum of the indicator cannot very well be made to vary its velocity exactly in the same way.

It will be obvious that air is here compressed without any intermediate transformation of power, and therefore the three sources of loss of power referred to in the beginning of this paper are reduced to one. The other unavoidable sources of loss are also small. The fluid friction is merely that in a plain pipe of no considerable length, and the moving parts are very few and such movement is slow. The efficiency, therefore, is, as a necessary consequence very high, amounting to 80 %. That is, the work done, measured in Isothermic compression of air, is 80 % of the gross power of the water. When we compare this with the 30 % or 35 % (and not always that) which is commonly attained in piston compressors driven by water wheels, it must be admitted that the question of the use of compressed air assumes a totally new aspect In a great variety of cases, where with a low efficiency it is not worth while to use compressed air, or where electrical transmission, for instance, may be obviously preferable to transmission by compressed air, the case is entirely reversed if anything like an efficiency of 80 % can be attained, and attained in machines of simpler and less costly description than that which they supersede.

Experience with this engine has revealed still further possibilities of improvement. Finality has not been reached. The author does not say that an efficiency of 80 % can be bettered, but in other directions, such as making an engine of the same size do more work, this engine will be improved on in subsequent engines and other developments of the same principle have also been suggested by it which are not yet carried out in practice.

DISCUSSION.

Mr. W. J. JENKINS, referring to the author's statement that all the work done in compressing air was converted into heat, but when air was compressed under such conditions that all the heat was instantly and entirely absorbed by surrounding solid or liquid bodies, only about half as much net work was exerted as when no heat was thus absorbed, said he thought there was a slip in this statement. The ratio between the isothermal and adiabatic compression would be about 1 to 1·27 for the final pressure mentioned.

He quite agreed that it was practically impossible to use as much water as would cool down the air to the original temperature in any ordinary compressor. He had had a good deal of experience with two stage compressors for low pressures, and had never found it advantageous in compressors cooled from the outside and without injection to use more than the amount the author mentioned, $\frac{2}{3}$ or $\frac{3}{4}$ the weight of air compressed in water. They could not even by the most scientific two stage compressors extract more than half the total heat generated.

As regards Mr. Taylor's machine, if Mr. Pearsall had favoured them with a sketch of that wonderful compressor, it would have called attention to a thing in it which a good many people would say was one of the impossibilities of engineering. Air was compressed to 100lbs. per square inch by a head of only 12 feet of water. They gave good results as regards efficiency, although in one case, in America, the pipe was about 9ft. diameter, so that there was some expense in putting them down.

The great drawback up to the present in compressing air by direct water power was the same as that which caused the throwing out of the compressors at the Mont Cenis tunnel.

Very large expense had to be incurred in laying down the plant, and only a very small output was obtainable from it. The plant at the Mont Cenis tunnel was exceedingly expensive, and the results obtained from it were very poor. He believed the total cost of two of the machines was about £7,000, and the amount of air turned out was about 8,000 cubic feet per hour each, or an expenditure of £3,500 for 8,000 cubic feet of air turned out per hour. That amount of air could be very well compressed by a steam driven compressor costing not more than £400, and he thought the engineers would have been wiser if they had adopted the steam engine at the first, as they did so finally.

Mr. Pearsall's wonderful apparatus was one of those which, in utilising the forces of nature in a scientific manner, arrived at an object in a very simple way, but he should like to know more as to how the author measured the amount of compressed air delivered, because on that point all the question of efficiency depended. In making tests of air compressors driven by steam engines, he had found great discrepancies between what different people said a compressor did and what it would actually do when the air was measured into a receiver. He had never been able to convince himself that they could actually measure compressed air by any method except the system of actually pumping it into a receiver at a definite pressure. In testing single-stage air compressors delivering air at 60lbs. per square inch, for example, he had found it extremely rare to get an actual measured delivery efficiency exceeding 80 per cent., although the indicator diagrams from the compressors showed quite 95 per cent. The difference was due to the effect of the heated passages and the walls of the cylinders. A thermometer placed in the delivery pipe from such a cylinder would generally show 350° F., as the final temperature of the air; and, of course, the walls of the cylinder would be at a temperature somewhat lower, but still at a high temperature. Now the air entering

the cylinder during the succeeding suction stroke, immediately became heated by contact with, and radiation from, the cylinder, and it is thereby expanded, so that the actual weight of air in the cylinder at the commencement of the compression stroke was much less than the weight of an equivalent volume of atmospheric air. This difference was shown only by the contents of the air receiver, after the air is cooled to the atmospheric temperature. Measurements of the indicator diagrams for delivery are consequently unreliable, and yet they are almost universally used as data upon which to base an estimate of the efficiency.

One of the principal advantages of the two-stage method of compression was the low temperature of the cylinders. It is easy to keep below 150° F., even with jacketted cylinders. Lower temperatures are usual with injection, but there are numerous other drawbacks, some of which apply equally to Mr. Pearsall's plan. He should like to know whether the author actually measured the air with a receiver or took the volume of his pump or air chamber and counted the number of strokes, because in the latter case the result would be somewhat wrong.

Did the drawing show a valve above the grid C, or was the valve on the outlet pipe shown on the top left-hand side of the chamber?

Would it be possible to compress say to 90 lbs. pressure with a fall of 10 or 12 ft?

The great drawback to any hydraulic system of direct compression was of course the immense quantity of water that must be dealt with, and this would, he thought, militate to a very large extent against Mr. Pearsall's system, except where there were large rivers and plenty of water power available. Of course in England they found few rivers big enough to drive turbines. No doubt in the Colonies and other places where there was plenty of water power obtainable, Mr. Pearsall's apparatus

would meet with considerable success. It was a simple apparatus and very suitable for use in such countries.

Mr. E. G. CONSTANTINE said he knew of a case where a large compressing plant was used for driving rock drills, hydraulic motors, &c., in a mine. Considerable friction arose between the engineer who had charge of the plant and the mine captain, and the former had frequently been hauled over the coals for not keeping up the supply of compressed air. The engineer said it was not his fault, his compressors were in good condition and working satisfactorily, as indicated by the gauge on the receiver. The mining men must be leaving the cocks open down below on the motors after blowing out the water. What was required was some apparatus to be fitted to the outflow pipes leading down to the mine, and to register, even if approximately, the quantity of air which had passed from the compressor to the mine. Was there any apparatus suitable for this purpose ?

Mr. THOMAS DANIELS asked for further information as to the fluid friction in the pipe in the Frizell Compressor.

Mr. ALFRED SAXON asked the author in what direction it was likely that his apparatus for compressing air would be useful in place of other forms of power application that were available, supposing that there was the necessary water power. No doubt in taking up this matter and simplifying and improving the machine, the author had in mind some probable demand for this class of machine, either in tunnel boring, drilling coal, or mining work of some kind. Where did the author think it would come in and be able to compete with other classes of transmission in use in various parts of the country, such as electricity, steam engines, &c.

Mr. PEARSALL, referring to Mr. Daniels' question, said if they took an inverted syphon in which water streamed down and up

again, and squirted some air-bubbles into the water as it went down, the water would obviously carry them down to a certain extent, and the object of the Frizell apparatus was simply to get the bubbles down to the bottom of the well. If they could do this, there would be a column of water equal to the whole depth of the well, and if they made a well 150ft. deep below level of tail race and got the bubbles of air down to that depth, they would obviously be compressed to a pressure of 150ft. or nearly five atmospheres. The difficulty was to get them down, because if the bubbles were at all large they ascended through the water very rapidly, so that unless the downward velocity of the water was pretty fast, they escaped almost as fast as they were put in. If they could make the bubbles small enough they rose through the water very slowly, so that a large part of the air did get down to the bottom of the well.

In doing so, however, the water encountered a large frictional resistance. The whole mass of water must be full of these innumerable bubbles, and there was an exceedingly great amount of surface friction. This particular analysis of the efficiency of the machine was, he believed, new. The machine had been described by Frizell, an eminent American engineer and other gentlemen at various times, but they always persisted in giving an account of possible efficiency different to that which he gave. The machine was very simple. Nothing could apparently be simpler than to make an air compressor machine consisting simply of a pipe, but the practical drawbacks were unfortunately so great as to give it scarcely any chance of a large sphere of usefulness.

To begin with, to dig a well 150ft. deep or more was, of course, no trifle. The pipe had to be enormous and it was not very powerful. They could not get an efficiency of more than about half. It was, however, a matter of great scientific interest.

In reference to Mr. Jenkins' remark about the work of adiabatic compression, he had no authorities by him, but he thought if Mr. Jenkins would refer to them again he would find that he was mistaken in his statement as to the ratio between isothermal and adiabatic compression. In such a comparison we must compare compression to the same volume and not to the same pressure, because on the subsequent cooling of the air in the receiver or in the pipes the pressure falls to that due to isothermal compression whatever it may have been when the air was compressed. The mean net pressure of compression and entry of air when compressed to one-fifth of its original (atmospheric) volume is, for adiabatic compression 47·1 lbs. per square inch, and for isothermal compression 25·4lbs. per square inch.

As to the Sommeiller machine at Mont Cenis, it was only able to make three strokes per minute, and the reason why so little work was done was that between each stroke it had to make long pauses, so that it turned out to be a very expensive machine. He thought, however, that the difficulty had been remedied.

As to measuring the air, he certainly should never dream of measuring from the cylinder, even in a piston compressor. They could not get even an approximation by doing that, and with these water machines it would be still more decidedly impossible. On many occasions he had pumped the air into a spare air-vessel. The simplest way of doing this was to pump into a small air-vessel, communicating with another vessel by a pipe having a two way cock, or a branch with a separate cock, and when a steady regular pumping was established, and it was blowing off at the open cock, this must be shut at a given instant and the cock into the other air-vessel opened, the observer taking notice of the time and the rise of the pressure in the second air-vessel. The air-vessel at the first was full of atmospheric air, and the gauge would rise in pressure say 5lbs.

every minute up to any pressure it was pumped up to. By that method the exact quantity of air compressed could be obtained.

Another, perhaps, better way was to fill up the second air-vessel with water and then at a given instant of time turn the air into the air-vessel and also open a tap below, so that the air came in and drove the water out. The pressure in the second vessel was thus kept constant at about 60 lbs., and the measure of the air pumped in was simply the measure of the water that came out. Either of the above methods were absolute measures.

In reply to Mr. Constantine, of course, if they could conveniently establish a receiver for measuring the air, it was the best way and should be adopted, but in the case mentioned this might be troublesome, and it would probably be more convenient to know at any moment how much air was passing. He did not see why they should not put a small meter up on the pipe, which would tell at any moment the quantity passing. There was an exceedingly simple arrangement of this kind called the "Venturi."

Air could certainly be compressed to 90 lbs., with a fall of from 10 to 12 ft., without any difficulty whatever. As to the field for the hydraulic machines, there was of course very little water power in England and therefore no great field for them, but in all countries where there was large water power the scope for such apparatus was more extensive. Broadly, wherever they wished to transmit the power of water to any considerable distance they had practically three ways of doing it—electricity, water pipes, or air pipes. It was really a question in each particular case as to which method they should adopt. His idea was that if the initial loss in compressing air, which had hitherto been so enormously great, could be very greatly reduced, the economy of transmitting power by compressed air

would be greater than the economy of transmission by electricity; this applied to a great number of cases, but not to all; distance was, of course, a great factor. At Niagara, there were three parts in the scheme with which the projectors commenced; one was to transmit power to an industrial city part of which was to be close to the falls, another was to distribute a great deal of the power to a distance of about four miles, and the third was to send power to Buffalo, twenty miles from Niagara. He had advised the use of compressed air for a distance of 4 miles and even more, and believed that power could be transmitted to such distances more economically in this way than by electricity. For distances as great as 20 miles (as for instance from Niagara to Buffalo) the case was not so clear, and it was quite likely electricity ought to be used. Knowing as he did the difficulties they had had in transmitting the power by electricity, he thought his anticipations had been probably correct.

There were a great many incidental advantages in using compressed air instead of electricity. One of them was that in taking power in the form of compressed air, a most extraordinary facility was offered for making use of any sources of heat that were available. Supposing they burned coal to heat the air, the coal thus burned produced power on a most effective scale, and its efficiency as a power producing agent was enormously greater that of coal used in an ordinary steam engine. It often happened that there were waste sources of heat that could be made use of in that way. If they transmitted air at 60° temperature, any source of heat that would warm it to even 10° more, would greatly increase its effect. In mining the advantages of compressed air scarcely admitted of question, even if it cost twice as much as electricity.

The PRESIDENT (Mr. Nasmith) moved a vote of thanks to the author for his interesting contribution, adding that it was quite

possible a simple apparatus such as the one described might be used in very large numbers where air compression was required.

Mr. T. ASHBURY, in seconding, said the members were much obliged to the author for bringing the paper before them, which gave information that was new to many of them.

The vote of thanks having been carried with acclamation, the proceedings closed.

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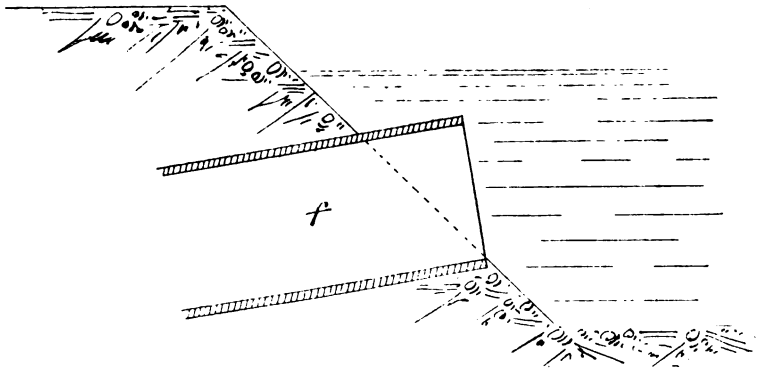
2 Plates follow illustrating this Paper.

UNIV. OF MICH

Plate 2.

T FOR COMPRESSING AIR.



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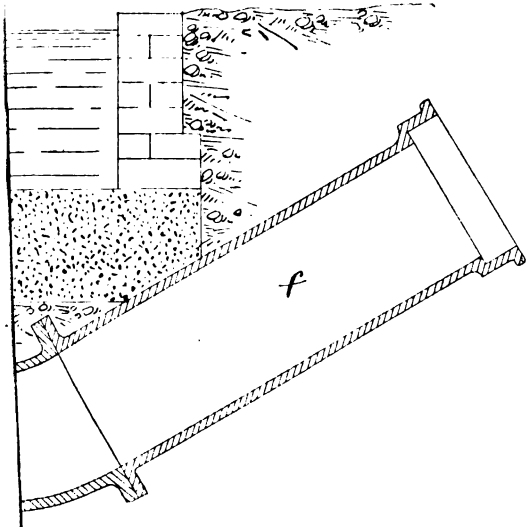

'S AIR COMPRESSOR.

UNIV. OF MICH.

42ND Annual Report

OF THE COUNCIL.

1897.

MANCHESTER
HERALD & WALKER, TYP., POOL FOLD CHAMBERS, OFF CHAPEL WALKS.
1898.

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1898.

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Past-President:

MR. JOS. NASMITH.

Treasurer:

MR. JAMES WALTHEW.

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Librarian:

MR. R. GASS,
19, City Road, Higher Openshaw.

Secretary:

MR. FRANK HAZELTON,
2, Croston Street, Brooks' Bar, Manchester.

ANNUAL REPORT OF COUNCIL,

1897.

The Council have pleasure in presenting the 42nd Annual Report of Proceedings.

To the membership roll during the year have been added—

6 Honorary Annual Members.
12 Ordinary Members.

Total 18

and after taking into account the loss by death, resignation, and erasure, the total number of names of all classes on the roll amounts to 386, as against 381 in the previous year, namely:—

26 Honorary Life Members.
129 Honorary Annual Members.
231 Ordinary Members.

386

Upon reference to the Financial Statement, as certified by the auditors (see pages 290-1), it will be seen that the balance standing to the credit of the Association, after payment of all accounts due up to the 31st December, amounts to £4,025 19s. 8d., as against £3,849 18s. 3d., at the close of the preceding year, thus showing a surplus of £176 1s. 5d. on the year's working.

They are pleased to report that during the year the payment to the superannuant members has been at the rate of 10s. per week, according to rule, as against the sum of 8/6 per week in the past year.

The number of recipients from this fund remains the same as at the commencement of the year—namely 5—no addition having been made thereto.

It is with profound regret the Council have to record that during the year death has removed the following members, brief memoirs of whom are appended on pages 282 to 289 :—

Carter, F. H.	Manchester.
Collins, A.	Do.
Marsden, B.	Do.
Ramsbottom, J	Do.
Tonge, R. F.	Do.

The following gentlemen have resigned their membership during the year : –

Duff, E. J.	Liverpool.
Fulton, D.	London.

The following gentlemen have ceased to be Members during the year :—

Holt, C.	Manchester.
Howarth, Ed.	Do.
Leech, J. R.	Do.
O'Brien, C.	Birmingham.
Oldham, H. W.	Stockport.
Quicke, W. G.	Manchester.

The following gentlemen have been added to the Membership Roll during the year :—

HONORARY MEMBERS.

Bellamy, A. R.	Stockport.
Dronsfield, J.	Oldham.
Forth, F. C.	Manchester.
Longridge, M.	Do.
Purves, J. H.	Do.
Royle, J. J.	Do.

ORDINARY MEMBERS.

Bagshaw, W.	Nottingham.
Cunliffe, R. W.	Manchester.
Dolby, F. C.	Do.
Eddisford, E. R.	Do.
Gibbins, A.	Birmingham.
Halliwell, C.	Manchester.
Heaton, J. S.	Do.
Mitton, J.	Do.
Turner, W.	Do.

Webb, F. H.	- - -	Liverpool.
West, F. J.	- - -	Manchester.
Whyatt, L.	- - -	Do.

During the year, 16 General Meetings of the Association have been held, 13 of which having been for literary or business purposes, one an excursion, and the remainder to social gatherings. The excursion was as follows:—

July 14th, Wednesday.—Port Sunlight, for inspection of Sunlight Soap Works. Attendance 70. See page 282.

PAPERS READ AND DISCUSSIONS HELD DURING THE YEAR.

Jan. 9.—**President's Inaugural Address, on "The way to meet Foreign Competition."**

,, 23.—Paper by Mr. Ed. J. Duff, Liverpool: **"Efficiency and Management of Steam Boilers."**

Feb. 27.—Paper by Mr. O. M. Row, Manchester: **"Transmission of Heat through Surfaces."**

Mar. 13.—Paper by Mr. Mark Robinson, M.Inst.C.E., London: **"On the use of High-Speed Engines for Mill Driving."**

,, 27.—Paper by Mr. W. Worby Beaumont, M.Inst.C.E., London: **"Motor Vehicles for Roads."**

Oct. 9.—OPENING SOCIAL MEETING at Grand Hotel. Address on **"Patents and Patent Law"** by the President, Mr. J. Nasmith.

,, 23.—Paper by Mr. W. T. How, London: **"Roller Bearings and their application."**

Nov. 13.—Discussion on Engineering Subjects: **"Wire drawn Steam,"** introduced by Mr. J. J. Royle. **"Clearance Spaces,"** introduced by Mr. A. Saxon. **"Ironfounding,"** introduced by Mr. J. Poole.

,, 27.—Paper by Mr. H. D. Pearsall, M.Inst.C.E., London: **"Hydraulic Plant for Compressing Air."**

In conclusion, the Council again desire to place on record their appreciation of the valuable services rendered to the Association by members and others in reading papers and contributing to the discussions during the year.

ANNIVERSARY DINNER.

The Forty-first Anniversary Dinner of the Association was held on Saturday, February 18th, at the Grand Hotel. Mr. Joseph Nasmith, the President, was in the chair, and there was a large gathering of Members.

Mr. John West, in proposing "Our Municipal Corporations," said that already Manchester men had received great benefits from one municipal enterprise—the connection of the Corporation with the Ship Canal Company,—and still greater benefits were in store for Manchester in the future. He said this because he was something of a convert. He never advocated the Canal himself, but he saw now as he had never done before what a decided good the Canal had been to the district.

Mr. Alderman Giles Atherton, Mayor of Stockport, responded.

Sir W. H. Bailey proposed "The Trade of the District." The toast was one, he said, which made them think of that bogey foreign competition. He thought it might be well that they should not sit by the waters of Babylon, and imitate the daughters of Jerusalem. (Laughter.) It would be well if those in a state of despair would look at their bank balances or read the statistics of that cheerful body the Manchester Statistical Society. (Laughter). If they studied the national balance-sheet they would find many things to make them feel hopeful, although particular trades perhaps might feel the severity of foreign competition. There had been a great deal said of the balance of trade. It seemed we had bought 15 millions sterling more than we had sent away in January, and we kept on buying more than we were selling, and had done for

some months past. If we had been able to purchase this 15 millions more than we had sold, that surely showed the purchasing power of the nation; and to study exports and imports in the old-fashioned way was surely fallacious and unworthy of Manchester men, who had studied the relations of trade with economics long ago. There were certain decayed trades in Lancashire. Certain rough industries were going, and certain common goods we were getting from the United States and Germany. His son had been over in the United States, and had found that for certain goods his own firm made and which were made in the United States, the men in the States could be paid 60s. a week in wages and produce a cheaper article than men paid 36s. or 38s. a week could produce here. The fact was that in the States they used finer tools. The toolmakers in the United States had a greater demand for their work than we had, and by the use of such tools, by dividing labour, and by making larger quantities the United States manufacturers had been able to beat us in some things. We must take a lesson from that fact, and give orders for more expensive tools that would somewhat minimise the cost of labour. (Hear, hear.) In the *Manchester Guardian* of that day there was a remarkable article in which it was stated that Messrs. Elder, Dempster & Co., were seeking to bring motor cars into competition with the Ship Canal. The finest motor car to-day was the locomotive. The locomotive on the railway would do more with one pound of coal than the steam carriage on the road would do with five. Even on a perfectly level road it took double the fuel that it did on the railway, and with the gradients it would take five times the amount. As the *Guardian* said, the motor car that could "carry goods 30 or 40 miles for nothing, at a profit, had yet to be invented, and nothing less would serve the purpose." (Laughter and applause.)

Mr. W. H. Holland, President of the Manchester Chamber of Commerce, responded. The trade and commerce of the district, he said, could not but be described as being in a fairly prosperous condition on the whole. It could not be denied, of course, that there were some trades which were doing badly. On the other hand, there were some paying uncommonly well, and they pulled up the average. He was glad to know that the engineering trade was in an exceptionally prosperous condition at this time. He thought the recent history of Manchester testified to the marked progress in the engineering industries of the district, and he did not know any more happy figures to be found in the Board of Trade returns published at the end of last year than those in which that assembly had a peculiar interest. (Hear, hear.) The policy of Free Trade embarked upon 50 years ago in this country, a policy from which he thought we had no desire to depart, had induced them all to adopt the best methods of production, and with such an equipment no wonder that the world's buyers, when they had any machinery to purchase, instinctively turned to the machine-makers and engineers of this country. He thought they might fairly hope that the advent of a new and highly important firm like that of Sir William Armstrong to this district would give some new impetus to the industry. (Hear, hear.) One could not think of that amalgamation without being reminded that Sir Joseph Whitworth did more than anybody else in his lifetime to secure the adoption of standards. Those standards he made had contributed in no small measure to the position the engineers and machine-makers of this country now occupied. For himself he had a leaning to the metric system, but he did think there was great advantage to be derived from uniformity of standard, and that uniformity Sir Joseph Whitworth did a great deal to secure. (Applause). One heard once again that an inclination was being shown to raise the American tariff. They would have thought that

the experience of the last high tariff was so unfavourable that the Americans would not be likely to return to that state of things. But if they liked to tax themselves highly, that was their policy. If America adopted a policy of Free Trade she would become at once a more formidable competitor in the markets of the world than she was now. (Hear, hear.) Mr. Holland expressed a hope that the engineering industry of the district would associate itself with the Manchester Chamber of Commerce. They would gladly welcome an engineering section of the Chamber. (Applause.) As Treasurer of the Indian Famine Fund he expressed his gratitude for the substantial support which had come from the engineering workshops. Then from the Operative Cotton Spinners' Association they had a grant of £2,000. The effect of such a contribution in India must be immense. (Applause.)

Mr. W. H. Collier (Manchester Ship Canal Company) also responded. The Ship Canal, he said, was of course to a large extent a close subject, for they were in competition with numerous other interests, and the problems that presented themselves were very complex. Some people thought that the methods of securing success were simple and straightforward. It was not so. Some thought they should go from warehouse to warehouse to solicit traffic. That might be a detail for individual lines of steamships when once established, but it was not the province nor was it the method of the Company. Success was to be obtained by methods quite different. What, for instance, was wanted was that when demands were made on the Company there should be large and extensive preparations beforehand to meet them. That meant the co-operation of the line of steamships, which line had to regard the jealousies of other lines, the arrangements made, and obligations entered into practically all over the world. There must be division of

territory in the way of business by the large lines; there was reciprocity and the holding from competition to a large extent. There were a hundred things to be considered. All these things had to be weighed, prepared, ripened, and attacked at one moment, and when that moment arrived the perfection of the preparations and the all-round consideration which had been given were the governing factors in the matter of success; and success was not always attained even when everything had been thought out. Many and large lines of business were in preparation, and he could say generally that the results of the work now being done would, there was reason to hope, be successfully presented at no distant date. In the business of the canal they had to judge of an endeavour of to-day six months hence, or more. (Hear, hear.) Things were not to be taken as sluggish because there might be a momentary check to progress. The receipts of the Company for the last twelve months would have been noted with great satisfaction. The year 1896 showed an increase over 1895 of some 40 per cent. in the receipts, and that was a large increase. (Applause,) If they could go on for some few years making the same rate of progress, one year on another, it would mean a great deal, and that was their hope. (Applause.) The future was full of hope, and though he could not enter into details, yet he could say they were fully justified in taking a cheerful view of things. (Applause.)

Mr. Frank Hazelton (Secretary) submitted the annual report of the Association.

Mr. George C. Haworth proposed "Success to the Association."

The Chairman, in responding, pointed to the wonderful extent and variety of the engineering trades of the district. He did not think there was a district in the kingdom or in the world which possessed so many engineering establishments as were to be

found within thirty miles of the Manchester Exchange. As to the foreign competition, he ventured to say that the English man and the English youth had qualities which, properly developed, would lead to a greater prosperity in the trade of the country than had ever been attained in the past. (Applause.) In regard to the Association, he thought they ought to have a larger membership.

The music was in charge of Mr. J. H. Greenwood, who had the assistance of Messrs. Turner, Grimshaw, Griffiths, and Marsland.

LIBRARY.

The following new books have been purchased and added to the Library:—

Steam Boilers.	G. Halliday.
,, ,, Construction.	W. S. Hutton.
Practical Management of Engines and Boilers.	W. Barnet le Van.
Marine Boiler Management and Construction.	C. E. Stromeyer.
Valves and Valve Gearing.	C. Hurst.
Slide Valves.	C. W. MacCord, junr.
Valve Gears for the Steam Engine.	C. H. Peabody.
Hydraulic Machinery.	R. G. Blaine.
Hydraulics.	Mansfield Merriman.
Pump Construction.	P. R. Bjorling.
Engineering Estimates, Costs and Accounts.	F. G. Burton.
Refrigerating and Ice-Making Machinery.	A. J. Wallis-Tayler.
Modern Gas and Oil Engines.	F. Grover.
Constructive Steam Engineering, embracing Engine Pumps and Boilers.	Jay M. Whitham.
Theory of Turbines.	De Volson Wood.
Electric Smelting and Refining.	W. Borchers, translated by W. G. McMillan.
Electric Lighting Installations. Three volumes. I. Accumulator. II. Apparatus. III. Application.	Sir D. Salomans.
Motive Power & Gearing for Electric Machinery.	Carter.
Indicator Practice and Steam Engine Economy.	F. F. Hemenway.
Wrinkles and Recipes.	Benjamin.
"Ironfounder" Supplement.	Bolland.
Metals: Their Property and Treatment.	A. K. Huntington.
Materials of Engineering: "Metal."	R. H. Thurston.
Manufacture of Iron and Steel Tubes.	C. R. Mark.
Rope Driving	J. J. Flather
Mechanics of Pumping Machinery	Weisbach & Hermann.

The Council have pleasure in acknowledging the following donations to the Library:—

Marine Engineers, their Qualifications and Duties.
Presented by the Author, Mr. E. G. Constantine, Member.

The Association exchanges Transactions with the following :—

American Institute of Mining Engineers.
,, Society of Mechanical Engineers.
Canadian Society of Civil Engineers.
Engine, Boiler, and Employers Liability Insurance Company.
Franklin Institute, America.
Institution of Civil Engineers of England.
,, Engineers and Shipbuilders in Scotland.
,, Mechanical Engineers.
Iron and Steel Institute.
Liverpool Engineering Society.
Manchester Geological Society.
,, Literary and Philosophical Society.
Midland Institute of Mining, Civil, and Mechanical Engineers.
Mining Association and Institute of Cornwall.
Mining Institute of Scotland.
North of England Institute of Mining and Mechanical Engineers.
North-East Coast of Engineers and Shipbuilders,
South Wales Institute of Engineers.
Society of Engineers.

The following Publications are received periodically :—

Cassier's Magazine.
Colliery Guardian.
Engineering Magazine.
Electrical Review.
Engineer.
Engineering.
Industries and Iron.
Iron and Steel Trades' Review.
Marine Engineer.
Mechanical World.
Practical Engineer.
Textile Mercury.
,, Recorder.
,, Manufacturer.

REPORT OF EXCURSION.

VISIT TO SUNLIGHT SOAP WORKS.

On Wednesday, the 14th July, upwards of 70 Members and lady friends visited Port Sunlight, Bebbington, near Birkenhead, for the purpose of inspecting the Sunlight Soap Works and Village.

The Party left the Central Station (Cheshire Lines) by the 12-30 noon train, and on arrival at Liverpool proceeded by the Mersey Railway to Bebbington.

The visitors were courteously received by the management, and conducted through the various departments of the vast works.

On the conclusion of the inspection the party returned to Liverpool, where a substantial tea was served at the Exchange Station Hotel.

Subsequently, on the motion of the President, Mr. Jos. Nasmith, seconded by Mr. Henry Webb, a cordial vote of thanks was passed to Messrs. Lever Bros. for the privilege accorded to the Association.

The party returned to Manchester by the 8-30 p.m. train.

OBITUARY.

Frederick Heathcote Carter was elected an honorary member of the Association in 1894. He commenced his professional training with Messrs. Measure Bros., London, with whom he remained five years. He subsequently started business in Manchester on his own account, being principally connected with the construction of ironwork and roofs of public buildings. He died suddenly in October, 1897, in the forty-first year of his age.

Arthur Collins was elected an ordinary member of the Association in 1894. He served his apprenticeship with the Worcester Engine Company. Subsequently, in addition to minor

engagements at home and abroad, he was foreman erector for Messrs. Tangyes Ltd., and latterly was the Manchester district superintendent engineer for the firm. He died suddenly on the 15th July, age 46, and was interred at the Southern Cemetery.

Richard Fletcher Tonge was elected an honorary member of the Association in 1884. He received his training with the firm of Messrs. Lancaster and Tonge, with whom he was connected at the time of his death, which occurred suddenly on the 21st February, in his fortieth year.

John Ramsbottom died at his residence, Fernhill, Alderley Edge, Cheshire, on the 21st May, in his 83rd year, with a full record of good work, and to the regret of a wide circle of friends. He was born on September 11, 1814, at Todmorden, in Yorkshire, and started his engineering education uuder his father; subsequently he was engaged with Messrs. Sharp, Roberts and Co., Manchester, where he first became associated with the design and building of locomotives.

In 1842 he entered the service of a railway which subsequently became part of the London and North-Western system—the Manchester and Birmingham line, with workshops at Longsight, where Ramsbottom was engaged for 15 years. In 1846 the line was taken over by the London and North Western Company, but Mr. Ramsbottom continued as locomotive superintendent of their northern and north-eastern sections, and in 1857 succeeded Trevithick at Crewe. At that date the London and North-Western Railway Company had two important locomotive works, namely, at Crewe and Wolverton, belonging to the northern and southern divisions respectively; but five years later the centralization of the locomotive work at Crewe was carried out, the Wolverton shops being utilised for

carriage building. With the adoption of Crewe as the chief locomotive centre commenced the wonderful development of these works, which has continued ever since, and which has made Crewe the object of pilgrimages by railway engineers from all parts of the world.

Ramsbottom was a sound mechanic, and in his organisation of the Crewe Works he paid the greatest attention to the facilities for the economical manufacture and maintenance of his engines. He recognised to the full the advantages of thorough interchangeability of parts, and he carried out the system of working to standard gauges to an extent which was then quite new in railway practice. Not only were new parts made accurately to standard dimensions, but a series of graduated sizes were adopted for the renewal of worn details. Special tools also were freely introduced at Crewe, and special attention was paid to the convenient handling of work and its transport from one department to another. It would be impossible within the limits of a notice like the present to deal with these matters in detail, but reference may be made to the extensive introduction of cranes driven by high-speed cotton ropes—and particularly to Mr. Ramsbottom's single-rail crane, a design so convenient in crowded workshops—and to the development of the system of railway of 18-in. gauge which does such admirable duty at Crewe. The introduction of locomotives on this system of narrow gauge lines was first made in May, 1862.

Ramsbottom was pre-eminently a master of detail, and he left the mark of his individuality on all his work; while many of the improvements he designed have been widely adopted outside the field of locomotive practice. Amongst these is the well-known piston ring introduced by him in 1852, and the prominent feature of which is that, owing to its initial form, it exerts by its own elasticity an equal radial pressure on the cylinder in

all parts of its circumference. It is too late in the day to offer any comment on the subject; but it should be understood that changes were then, as now, regarded with suspicious reserve. Ramsbottom, however, was able to offer convincing testimony of the efficiency of the ring. He was able, for instance, to tell the members of the Institution of Mechanical Engineers, in 1854, that a piston ring in a locomotive had run for 15 months, traversing 19,650 miles, the ring costing when new only 2s. 6d., while there was a substantial reduction in the quantity of steam used. In the following year he described to the same Institution the process of manufacturing the rings. Other details of the locomotive—amongst them the now almost universally used arrangement of twin safety valves—formed the subjects of similar contributions to the Institution in 1856 and 1857.

It was about this time, too, 1856, that Ramsbottom commenced to experiment with the supply of water from troughs laid in the track to locomotives running over them; but it took many years to convince his *confrères* in the railway world that there was not abnormal retardation. The system, which has been yearly growing in importance, was, however, fairly introduced in 1860, and he was able to show in his paper, read before the Institution of Mechanical Engineers in 1861, that the variation in delivery was very slight at any speed over 22 miles an hour.

Ramsbottom was one of the earliest believers in steel as a substitute for iron, and he not only used it freely, but developed its manufacture at Crewe. A Bessemer plant had been laid down at Crewe early in the sixties; but it was found in some instances that the weight of the anvil of any steam hammer for working heavy forgings was inconveniently great; and Ramsbottom devised his system of laying two hammers on their sides to act horizontally in opposite directions with the bloom placed between them. First, a 10-ton horizontal duplex hammer was

made for experiment, and the success realised resulted in a 30-ton hammer being constructed. The 10-ton plant was used in roughing steel tyres before they went to the Rothwell Jackson Mill.

While speaking of the steel plant at Crewe, mention may be made of the new system of manufacturing steel tyres which Ramsbottom introduced there about 1866. According to this plan the tyres are made from conical ingots—a form suggested by Mr. F. W. Webb. now chief mechanical engineer of the London and North-Western Railway—these ingots being forged by means of the duplex hammer, reduced to a disc form, punched by a conical punch, and forged to the form of a steel ring, suitable for rolling out to a tyre in the tyre mill. This system of manufacture formed the subject of a paper read by Mr. Ramsbottom before the Institution of Mechanical Engineers as their Manchester meeting, 1866.

About this time also Mr. Ramsbottom made several improvements in reversing rolling mills, and a few years later he interested himself in the ventilation of railway tunnels by mechanical means, and successfully carried out such a system of fan ventilation at the Edgehill tunnel at Liverpool.

Of Mr. Ramsbottom's locomotive practice it is unnecessary that any lengthy reference should be made here, as its features are matters of common knowledge amongst railway engineers. He was an advocate for comparatively light engines, and introduced types which successfully held their own for many years, even in the face of the growing demands of traffic. As to the general efficiency of his engines, striking testimony is borne by the fact that, although 30 years old, locomotives of the "Lady of the Lake" type were used for light loads at high speed in the railway race to Scotland in 1888.

Although, owing to failing health, Mr. Ramsbottom had to relinquish the onerous duties of locomotive superintendent to

the London and North-Western in 1871, he was for long years afterwards consulted on several points, and in this capacity also gave the results of his experience to the Lancashire and Yorkshire Company, especially in the design and construction of the new works at Horwich. He subsequently became a director of this latter company, a position which he only recently resigned. He was also one of the directors of Beyer, Peacock, and Co., Limited, and took a lively interest until the last in Owens College, Manchester, of which he was a Governor. Some years ago the honorary degree of Master of Engineering was conferred upon him by the University of Dublin.

He was elected a Life Honorary Member of the Association in March, 1890.

Mr. Benjamin Marsden died on the 30th January, in his 59th year. He was elected a Life Honorary Member of the Association in the year 1882. He was the principal of S. Marsden & Sons, Limited, bolt and nut makers, of Manchester. Mr. Marsden was well-known throughout the iron trade of Lancashire, and had been closely identified with the trade for nearly 50 years, the works, which were established by his father in 1845, having been practically under the control of Mr. Benjamin Marsden for the last 30 years, and, under his management, they have been steadily developed, until they are by far the largest works of their kind in Lancashire, giving employment to about 400 hands, and fitted with all the most modern plant and machinery—a large portion of their own special design and construction. Mr. Marsden recently twice paid a visit to the United States in order to make himself acquainted with the best American improvements in his particular line of trade, and one special result was the introduction of oil furnaces for heating the bar iron used in the

manufacture of bolts, a complete plant of which has been for some time in operation at the Manchester works, whilst the firm has also manufactured and sold a large number of these furnaces to other works in the trade. Mr. Marsden was closely identified with all the trade interests of the district.

To many members who were intimately acquainted with Mr. Marsden, the following notice written by a personal friend may not be unacceptable:—

I am not sure that the name of Mr. Benjamin Marsden will occur to many outside our city and Heaton Moor, where it has for 20 years been held in deservedly high respect. Ben Marsden was in many ways a remarkable personality, and raised himself from comparatively humble beginnings to be one of the captains of industry in Lancashire. When that great inventor Sir Joseph Whitworth gave to the mechanical world the screw thread established by mathematical accuracy, and forming a standard that to this day has never been improved, hand-made bolts and nuts were costly, inaccurate, and untrustworthy. The opportunity came, and with it the man. Marsden saw that as absolute accuracy was the principle of the Whitworth thread, so must absolute accuracy be obtained in the manipulation of the same, and his inventions and improvements in bolt and nut making machinery were no inconsiderable factor in other constructive industries where strength, proportion, and symmetry were aided by the element of bolts, nuts, and screws. But Mr. Marsden was more than a mere mechanical inventor. He placed at the service of his neighbours the ripe experience, grasp of detail, accuracy of judgment and untiring energy that make the ideal clerk of works, without whom the architect and designer would be mere theorists. Ten years since he superintended as honorary clerk of works the erection of the Reform Club on Heaton Moor, and last year with a zeal and devotion that perhaps shortened his days,

he rendered the same honorary services in the building of the Congregational Church. These services are held in grateful remembrance to-day by hundreds. A man of few words, he needed a good deal of knowing, but beneath that brusque manner and within the hard shell of reserve there beat as kind a heart and as tender a nature as friend or neighbour could desire. The wand he wielded was his pencil. Give him a house, workshop, or church to plan, and he was as near the mark with his pencil as the surveyor with his scale. Strong common sense was his forte; planning and constructive scheming his foible.

The green sod of the Southern Necropolis has rarely covered a keener perception, a stronger will, a kindlier heart, or an honester man than Benjamin Marsden. He was interred at the Southern Cemetery, February 3rd, 1897.

TREASURER'S GENERAL CASH ACCOUNT, for the year ending 31st December, 1897.

Dr. (Including Superannuation Fund Account.) **Cr.**

1897.		£	s.	d.
Jan. 1.	To Balance as per last Report	8,849	18	8
Dec. 31.	„ Contributions and Entrance Fees	580	1	0
	„ Interest from Mortgages on Properties £114 5 0			
	„ „ „ Leeds Corporation 3½ % Stock 20 6 0			
	„ „ „ Bank 0 7 5			
		184	18	5
		£4,514	17	8

Audited and found correct

J. E. KELSALL,
W. ORMEROD,
J. PARRY,
} AUDITORS.

Sept., 1897.
12th Jan., 1898.

1897.		£	s.	d.
Jan. 1.	By Rent—Grand Hotel	20	0	0
to	„ Secretary's Salary £45 0 0			
Dec. 31.	„ Librarian's „ 10 0 0			
		55	0	0
	„ Superannuation Allowance	123	1	0
	„ Printing and Lithography of Transactions £126 8 0			
	„ Binding of do. 18 3 0			
	„ General Circulars and Miscellaneous Work 17 3 3			
	„ Stationery 3 14 0			
		165	8	3
	„ Insurance premium on Library	0	6	0
	„ Expenses re Anniversary Dinner	15	7	6
	„ Audit, General Council and Sub-Committee Exs. £21 12 3			
	„ Postages of Papers, Circulars, and Correspondence 29 8 3			
	„ Sundries 16 6 9			
		67	7	3
	„ Delivery of Annual Volumes	5	9	0
	„ New Books for Library	12	19	0
	„ Repairs to Library Case	7	7	0
	„ Expenses re Mr. Beaumont's Paper £4 1 0			
	„ „ „ Mr. Pearsall's Paper 3 0 0			
		7	1	0
	„ President's Exs. re Mechanical Engineers' Dinner £2 10 0			
	„ „ „ Scottish „ „ 2 2 0			
		4	12	0
	„ Cash invested in Building Society £50 0 0			
	„ „ „ Properties: Mortgages 3,050 0 0			
	„ „ „ Leeds Corporation 3½ % Stock 600 0 0			
	„ „ „ Premium on do. 90 6 6			
		3,790	6	6
	„ Cash in Bank £201 8 8			
	„ „ Treasurer's hands 31 3 5			
	„ „ Secretary's „ 3 1 6			
		235	13	2
		£4,514	17	8

SUPERANNUATION FUND ACCOUNT, for year ending 31st December, 1897.

Dr. (Included in General Account.) **Cr.**

1897.		£	s.	d.	£	s.	d.
Jan. 1.	To Capital invested as per Resolution passed at the Half-yearly Meeting, 14th June, 1879	2,100	0	0			
	,, Additional Capital voted at the Annual Meeting, 13th December, 1889	300	0	0			
	,, Additional Capital voted at the Annual Meeting, 12th December, 1891	600	0	0			
	,, Ditto, 11th December, 1897 ..	500	0	0			
					3,500	0	0
	,, Balance from last Report				65	13	4
Dec. 31.	,, Twelve Months' Interest on above Capital Invested as per Rule				114	11	0
					£3,680	4	4

1897.		£	s.	d.	£	s.	d.
Jan. 1. to Dec. 31.	By Superannuation Allowances :— Mr. John R. Wolstenholme	24	1	0			
	,, William Holmes.....	26	0	0			
	,, John Dutton	26	0	0			
	,, James Schofield	26	0	0			
	,, E. Kershaw.....	26	0	0			
					128	1	0
	,, Balance to credit of Superannuation Fund Account.....				3,552	3	4
					£3,680	4	4

Audited and found correct,

12th January, 1898.

J. E. KELSALL,
W. ORMEROD,
J. PARRY,
} AUDITORS.